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Derivation and Analysis of Block Hybrid Method for Solving Initial Value Problems in Oscillatory Differential Equations

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Abstract

The Block Hybrid Method is a numerical technique for solving ordinary differential equations (ODEs), particularly effective for stiff and oscillatory systems. This paper introduces a new method designed to handle challenges posed by equations like the Malthusian Growth Model and Prothero-Robinson equation, which are difficult to solve using conventional methods due to stiffness and rapid oscillations. Derived using power series approximation, the method is analyzed for order, error constant, consistency, and zero stability, proving to be convergent, consistent, and zero-stable. Numerical examples demonstrate its superior accuracy and stability compared to existing methods, making it a valuable tool for solving complex initial value problems in real-world applications.

Keywords: Numerical Methods, Oscillatory Differential Equations, Computational Efficiency, Stability Analysis, Block Hybrid Method

1   Introduction

To tackle real-world challenges across engineering, biological sciences, physical sciences, electronics, and other disciplines, researchers frequently encounter initial value problems, as noted by [1]. Many practical problems in engineering and science are initially formulated as differential equations before resolution. These equations typically involve derivatives, establishing a connection between an independent variable, a dependent variable and one or more differential coefficients concerning x [2, 3]. Although discrete hybrid methods have been devised, their superior accuracy compared to conventional linear multi-step methods of identical step-size, as highlighted by Lambert in [4], has not yet garnered the anticipated level of attention. This study aims to address initial value problems (IVPs) structured as:

$$y'(x) = f(x, y), \qquad a \le x \le b, \qquad y(a) = y_0 \qquad (1.1)$$

The Block Hybrid Method is a numerical technique used to solve ordinary differential equations (ODEs), particularly stiff systems, with higher accuracy and efficiency. It combines the advantages of both multistep methods and Runge-Kutta methods, providing a robust solution for a wide range of differential equation problems [4]. The Block Hybrid Method offers a versatile and efficient approach to solving ordinary differential equations, especially in scenarios involving stiff systems, making it a valuable tool in the numerical analysis toolkit [3, 5].

The Malthusian Growth Model, Prothero-Robinson equation and highly stiff oscillatory differential equations are important examples of initial value problems (IVPs) in numerical analysis. The Malthusian Growth Model, introduced by Thomas Malthus, describes exponential population growth under the assumption of unlimited resources, where the rate of change in population is proportional to the current population size [6, 7]. This model is fundamental in understanding population dynamics and is often used in ecology and economics. Its simplicity, represented by the first-order differential equation $\dfrac{d\rho}{dt} = \kappa\rho$, where ρ is the population size and κ is the growth rate, allows for easy analytical solutions. However, more complex biological systems require extensions of this model to capture factors like resource limitations or carrying capacities, introducing nonlinearities and complexity into IVP formulations [8, 9].

The Prothero-Robinson equation and stiff oscillatory differential equations present significantly more challenging problems. The Prothero-Robinson equation highlights the difficulties posed by stiffness, a property of differential

equations where certain components evolve much faster than others, leading to numerical instabilities [10, 11]. This equation is used to test the robustness of numerical methods, especially in systems involving multi-scale phenomena. Highly stiff oscillatory differential equations, often encountered in systems involving mechanics, physics and engineering, exhibit rapid oscillations that make their numerical solution particularly difficult [12, 13]. Traditional numerical methods struggle with accuracy and stability in such cases, necessitating advanced techniques like implicit methods or specialized solvers. Together, these models underscore the importance of selecting appropriate methods for solving IVPs, particularly when dealing with systems with diverse beha2viors such as exponential growth, oscillations, and stiffness [14, 15].

2 Derivation of the Block Hybrid Method

In this section, we will utilize the concepts introduced in preceding sections to construct block hybrid method aimed at solving first-order initial value problems in oscillatory differential equation expressed in the form (1.1). The power series as an approximate solution of the form;

$$y(x) = h \sum_{i=0}^{m+n-1} \alpha_j \chi^i \tag{2.1}$$

is consider deriving the method, where m and n are distinct point of interpolation and collocation [9].

2.2 Formulation of the Block Hybrid Method

The power series polynomial (2.1) is consider as an approximate solution of (1.1).

Differentiate (2.1) once to yield,

$$\frac{dy}{dx} = h \sum_{i=0}^{m+n-1} i \alpha_j \chi^{i-1} \tag{2.2}$$

Where $\alpha \in \Re$ for $i = 0\left(\frac{1}{3}\right)2$ and $y(x)$ is continuously differential. Let the solution of (1.1) be sought on the integration interval $[a,b]$ with a constant step-size h defined by $h = \chi_{n+1} - \chi_n, n = 0, 1, \cdots, N$.

Substituting equation (2.2) into (1.1) gives,

$$f(x, y) = h \sum_{i=0}^{m+n-1} i \alpha_j \chi^{i-1} \tag{2.3}$$

We interpolate equation (2.1) at point, $x_{n+m}, m = \frac{1}{3}$ and collocate equation (2.3) at points

$x_{n+n}, n = 0, \frac{1}{3}, \frac{2}{3}, 1, \frac{4}{3}, \frac{5}{3}, 2$ to give,

$$A\chi = U \tag{2.4}$$

Where

$$A = [a_0, a_1, a_2, a_3, a_4, a_5, a_6, a_7]^T, U = \left[y_{n+\frac{1}{3}}, f_n, f_{n+\frac{1}{3}}, f_{n+\frac{2}{3}}, f_{n+1}, f_{n+\frac{4}{3}}, f_{n+\frac{5}{3}}, f_{n+2} \right]^T$$

$$X = \begin{bmatrix} \chi^0_{n+\frac{1}{3}} & \chi^1_{n+\frac{1}{3}} & \chi^2_{n+\frac{1}{3}} & \chi^3_{n+\frac{1}{3}} & \chi^4_{n+\frac{1}{3}} & \chi^5_{n+\frac{1}{3}} & \chi^6_{n+\frac{1}{3}} & \chi^7_{n+\frac{1}{3}} \\ 0 & 1\chi^0_n & 2\chi^1_n & 3\chi^2_n & 4\chi^3_n & 5\chi^4_n & 6\chi^5_n & 7\chi^6_n \\ 0 & 1\chi^0_{n+\frac{1}{3}} & 2\chi^1_{n+\frac{1}{3}} & 3\chi^2_{n+\frac{1}{3}} & 4\chi^3_{n+\frac{1}{3}} & 5\chi^4_{n+\frac{1}{3}} & 6\chi^5_{n+\frac{1}{3}} & 7\chi^6_{n+\frac{1}{3}} \\ 0 & 1\chi^0_{n+\frac{2}{3}} & 2\chi^1_{n+\frac{2}{3}} & 3\chi^2_{n+\frac{2}{3}} & 4\chi^3_{n+\frac{2}{3}} & 5\chi^4_{n+\frac{2}{3}} & 6\chi^5_{n+\frac{2}{3}} & 7\chi^6_{n+\frac{2}{3}} \\ 0 & 1\chi^0_{n+1} & 2\chi^1_{n+1} & 3\chi^2_{n+1} & 4\chi^3_{n+1} & 5\chi^4_{n+1} & 6\chi^5_{n+1} & 7\chi^6_{n+1} \\ 0 & 1\chi^0_{n+\frac{4}{3}} & 2\chi^1_{n+\frac{4}{3}} & 3\chi^2_{n+\frac{4}{3}} & 4\chi^3_{n+\frac{4}{3}} & 5\chi^4_{n+\frac{4}{3}} & 6\chi^5_{n+\frac{4}{3}} & 7\chi^6_{n+\frac{4}{3}} \\ 0 & 1\chi^0_{n+\frac{5}{3}} & 2\chi^1_{n+\frac{5}{3}} & 3\chi^2_{n+\frac{5}{3}} & 4\chi^3_{n+\frac{5}{3}} & 5\chi^4_{n+\frac{5}{3}} & 6\chi^5_{n+\frac{5}{3}} & 7\chi^6_{n+\frac{5}{3}} \\ 0 & 1\chi^0_{n+1} & 2\chi^1_{n+1} & 3\chi^2_{n+1} & 4\chi^3_{n+1} & 5\chi^4_{n+1} & 6\chi^5_{n+1} & 7\chi^6_{n+1} \end{bmatrix}$$

Solving (2.4), for $\alpha_i, i = 0\left(\frac{1}{3}\right)2$ and replacing back into (2.1) gives a linear block scheme as

$$y(t) = \alpha_{\frac{1}{3}}(t)y_{n+\frac{1}{3}} + h\left[\begin{array}{l} \beta_0(t)f_n + \beta_{\frac{1}{3}}(t)f_{n+\frac{1}{3}} + \beta_{\frac{2}{3}}(t)f_{n+\frac{2}{3}} \\ + \beta_1(t)f_{n+1} + \beta_{\frac{4}{3}}(t)f_{n+\frac{4}{3}} + \beta_{\frac{5}{3}}(t)f_{n+\frac{5}{3}} + \beta_2(t)f_{n+2} \end{array} \right] \tag{2.5}$$

Where

$$\alpha_{\frac{1}{3}} = 1$$

$$\beta_0 = \frac{1}{181440}\left(-19087 + 66918t - 93501t^2 + 64476t^3 - 21870t^4 + 2916t^5\right)(3t-1)^2$$

$$\beta_{\frac{1}{3}} = -\frac{1}{7560}\left(-2713 - 8139t + 43623t^2 - 66447t^3 + 4704t^4 - 16281t^5 + 2187t^6\right)(3t-1)$$

$$\beta_{\frac{2}{3}} = \frac{1}{60480}\left(15487 + 92922t - 262251t^2 + 243756t^3 - 98010t^4 + 14580t^5\right)(3t-1)^2$$

$$\beta_1 = -\frac{1}{11340}\left(+2344 + 14064t - 50112t^2 + 52812t^3 - 23085t^4 + 3645t^5\right)(3t-1)^2$$

$$\beta_{\frac{4}{3}} = \frac{1}{60480}\left(6737 + 40422t - 15830t^2 + 183276t^3 - 86670t^4 + 14580t^5\right)(3t-1)^2$$

$$\beta_{\frac{5}{3}} = -\frac{1}{7560}\left(263 + 1578t - 6507t^2 + 7992t^3 - 4050t^4 + 729t^5\right)(3t-1)^2$$

$$\beta_1 = \frac{1}{181440}\left(863 + 5178t - 22059t^2 + 28188t^3 - 15066t^4 + 2916t^5\right)(3t-1)^2$$

for $t = \frac{(\chi - \chi_n)}{h}$.

Evaluating (2.5) at non-interpolating points to gives

$$y_n = y_{n+\frac{1}{3}} + \psi_{01}f_n + \psi_{02}f_{n+\frac{1}{3}} + \psi_{03}f_{n+\frac{2}{3}} + \psi_{04}f_{n+1} + \psi_{05}f_{n+\frac{4}{3}} + \psi_{06}f_{n+\frac{5}{3}} + \psi_{07}f_{n+2}$$

$$y_{n+\frac{2}{3}} = y_{n+\frac{1}{3}} + \psi_{11}f_n + \psi_{12}f_{n+\frac{1}{3}} + \psi_{13}f_{n+\frac{2}{3}} + \psi_{14}f_{n+1} + \psi_{15}f_{n+\frac{4}{3}} + \psi_{16}f_{n+\frac{5}{3}} + \psi_{17}f_{n+2}$$

$$y_{n+1} = y_{n+\frac{1}{3}} + \psi_{21}f_n + \psi_{22}f_{n+\frac{1}{3}} + \psi_{23}f_{n+\frac{2}{3}} + \psi_{24}f_{n+1} + \psi_{25}f_{n+\frac{4}{3}} + \psi_{26}f_{n+\frac{5}{3}} + \psi_{27}f_{n+2}$$

$$y_{n+\frac{4}{3}} = y_{n+\frac{1}{3}} + \psi_{31}f_n + \psi_{32}f_{n+\frac{1}{3}} + \psi_{33}f_{n+\frac{2}{3}} + \psi_{34}f_{n+1} + \psi_{35}f_{n+\frac{4}{3}} + \psi_{36}f_{n+\frac{5}{3}} + \psi_{37}f_{n+2}$$

$$y_{n+\frac{5}{3}} = y_{n+\frac{1}{3}} + \psi_{41}f_n + \psi_{42}f_{n+\frac{1}{3}} + \psi_{43}f_{n+\frac{2}{3}} + \psi_{44}f_{n+1} + \psi_{45}f_{n+\frac{4}{3}} + \psi_{46}f_{n+\frac{5}{3}} + \psi_{47}f_{n+2}$$

$$y_{n+1} = y_{n+\frac{1}{3}} + \psi_{51}f_n + \psi_{52}f_{n+\frac{1}{3}} + \psi_{53}f_{n+\frac{2}{3}} + \psi_{54}f_{n+1} + \psi_{55}f_{n+\frac{4}{3}} + \psi_{56}f_{n+\frac{5}{3}} + \psi_{57}f_{n+2}$$

(2.6)

Evaluating (2.6) at $t = \left[\frac{1}{3}, \frac{2}{3}, 1, \frac{4}{3}, \frac{5}{3}, 2 \right]$ points to gives discrete block scheme of the form:

$$y_{n+\frac{1}{3}} = y_n + \Omega_{11}f_n + \Omega_{12}f_{n+\frac{1}{3}} + \Omega_{13}f_{n+\frac{2}{3}} + \Omega_{14}f_{n+1} + \Omega_{15}f_{n+\frac{4}{3}} + \Omega_{16}f_{n+\frac{5}{3}} + \Omega_{17}f_{n+2}$$

$$y_{n+\frac{2}{3}} = y_n + \Omega_{21}f_n + \Omega_{22}f_{n+\frac{1}{3}} + \Omega_{23}f_{n+\frac{2}{3}} + \Omega_{24}f_{n+1} + \Omega_{25}f_{n+\frac{4}{3}} + \Omega_{26}f_{n+\frac{5}{3}} + \Omega_{27}f_{n+2}$$

$$y_{n+1} = y_n + \Omega_{31}f_n + \Omega_{32}f_{n+\frac{1}{3}} + \Omega_{33}f_{n+\frac{2}{3}} + \Omega_{34}f_{n+1} + \Omega_{35}f_{n+\frac{4}{3}} + \Omega_{36}f_{n+\frac{5}{3}} + \Omega_{37}f_{n+2}$$

$$y_{n+\frac{4}{3}} = y_n + \Omega_{41}f_n + \Omega_{42}f_{n+\frac{1}{3}} + \Omega_{43}f_{n+\frac{2}{3}} + \Omega_{44}f_{n+1} + \Omega_{45}f_{n+\frac{4}{3}} + \Omega_{46}f_{n+\frac{5}{3}} + \Omega_{47}f_{n+2}$$

$$y_{n+\frac{5}{3}} = y_n + \Omega_{51}f_n + \Omega_{52}f_{n+\frac{1}{3}} + \Omega_{53}f_{n+\frac{2}{3}} + \Omega_{54}f_{n+1} + \Omega_{55}f_{n+\frac{4}{3}} + \Omega_{56}f_{n+\frac{5}{3}} + \Omega_{57}f_{n+2}$$

$$y_{n+1} = y_n + \Omega_{61}f_n + \Omega_{62}f_{n+\frac{1}{3}} + \Omega_{63}f_{n+\frac{2}{3}} + \Omega_{64}f_{n+1} + \Omega_{65}f_{n+\frac{4}{3}} + \Omega_{66}f_{n+\frac{5}{3}} + \Omega_{67}f_{n+2}$$

(2.7)

3 Analysis of Basic Properties of the Block Hybrid Method

The necessary and sufficient conditions for new method and their associated block method are analyzed to establish their validity. These properties include; order and error constant, consistency, zero-stability and region of absolute stability.

3.1 Order and Error Constant

This subsection establishes the linear operator $\ell[y(x_i); h]$ associated with the newly derived method.

Definition 3.1

A linear multistep method is of order p if it satisfies the condition

$$c_0 = c_1 = c_2 = c_3 = \cdots = c_p = c_{p+1} = 0, \, c_{p+2} \neq 0,$$

Where

$$c_0 = \sum_{j=0}^{k} \alpha_j$$

$$c_1 = \sum_{j=0}^{k} \left(j\alpha_j - \beta_j \right)$$

.

.

.

$$c_p = \sum_{j=0}^{k} \left[\frac{1}{p!} j^p \alpha_j - \frac{1}{(p-1)!} \left(j^{p-1} \beta_j \right) \right], \, p = 2, 3, \cdots, q+1$$

(3.1)

The parameter $c_{p+2} \neq 0$ is referred to as the error constant with the local truncation error defined as $x_{n+k} = c_{p+2}h^{p+2}y^{(p+2)}(x_n) + c_{p+3}h^{p+3}y^{(p+3)}(x_n) + c_{p+4}h^{p+4}y^{(p+4)}(x_n) + 0(h^{p+5})$

$$\begin{bmatrix} \sum_{j=0}^{\infty}\frac{\left(\frac{1}{3}\right)^j}{j!} - y_n - \sum_{j=0}^{\infty}\frac{h^{j+1}}{j!}y_n^{j+1}\left[\frac{2713}{7560}\left(\frac{1}{3}\right) - \frac{15487}{60480}\left(\frac{2}{3}\right) - \frac{586}{2835}(1) - \frac{6737}{60480}\left(\frac{4}{3}\right) + \frac{263}{7560}\left(\frac{5}{3}\right) - \frac{863}{181440}(2)\right] \\ \sum_{j=0}^{\infty}\frac{\left(\frac{2}{3}\right)^j}{j!} - y_n - \sum_{j=0}^{\infty}\frac{h^{j+1}}{j!}y_n^{j+1}\left[\frac{94}{189}\left(\frac{1}{3}\right) - \frac{11}{3780}\left(\frac{2}{3}\right) - \frac{332}{2835}(1) - \frac{269}{3780}\left(\frac{4}{3}\right) + \frac{22}{945}\left(\frac{5}{3}\right) - \frac{37}{11340}(2)\right] \\ \sum_{j=0}^{\infty}\frac{(1)^j}{j!} - y_n - \sum_{j=0}^{\infty}\frac{h^{j+1}}{j!}y_n^{j+1}\left[\frac{27}{56}\left(\frac{1}{3}\right) + \frac{387}{2240}\left(\frac{2}{3}\right) + \frac{34}{105}(1) - \frac{243}{2240}\left(\frac{4}{3}\right) + \frac{9}{280}\left(\frac{5}{3}\right) - \frac{29}{6720}(2)\right] \\ \sum_{j=0}^{\infty}\frac{\left(\frac{4}{3}\right)^j}{j!} - y_n - \sum_{j=0}^{\infty}\frac{h^{j+1}}{j!}y_n^{j+1}\left[\frac{464}{945}\left(\frac{1}{3}\right) + \frac{128}{945}\left(\frac{2}{3}\right) + \frac{1504}{2835}(1) - \frac{58}{945}\left(\frac{4}{3}\right) + \frac{16}{945}\left(\frac{5}{3}\right) - \frac{8}{2835}(2)\right] \\ \sum_{j=0}^{\infty}\frac{\left(\frac{5}{3}\right)^j}{j!} - y_n - \sum_{j=0}^{\infty}\frac{h^{j+1}}{j!}y_n^{j+1}\left[\frac{275}{1512}\left(\frac{1}{3}\right) + \frac{2125}{12096}\left(\frac{2}{3}\right) + \frac{250}{567}(1) - \frac{3875}{12096}\left(\frac{4}{3}\right) + \frac{235}{1512}\left(\frac{5}{3}\right) - \frac{275}{36288}(2)\right] \\ \sum_{j=0}^{\infty}\frac{(2)^j}{j!} - y_n - \sum_{j=0}^{\infty}\frac{h^{j+1}}{j!}y_n^{j+1}\left[\frac{18}{35}\left(\frac{1}{3}\right) + \frac{9}{140}\left(\frac{2}{3}\right) + \frac{68}{105}(1) - \frac{9}{140}\left(\frac{4}{3}\right) + \frac{18}{35}\left(\frac{5}{3}\right) - \frac{41}{420}(2)\right] \end{bmatrix}$$

Therefore, according to [13], the new method is of uniform order seven as well as error constant is given by

$$C_7 = \begin{pmatrix} 1.5460 \times 10^{-06} \\ 1.1321 \times 10^{-06} \\ 1.3677 \times 10^{-06} \\ 1.1218 \times 10^{-06} \\ 1.5926 \times 10^{-06} \\ 1.2661 \times 10^{-06} \end{pmatrix}$$

3.2 Consistent

Traditionally, the new method is consistent because the order of the method is order greater than or equal to one [3].

3.3 Zero Stable

By definition, the new method is said to be zero stable as $h \to 0$ if the roots of the polynomial $\pi(r) = 0$ satisfy $\left|\left[\sum A^o R^{k-1}\right]\right| \leq 1$, and those roots with $R = 1$ must be simple. Hence it's found as

$$\pi(r) = \left| r\begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} - \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \right| = \left| \begin{bmatrix} r & 0 & 0 & 0 & 0 & -1 \\ 0 & r & 0 & 0 & 0 & -1 \\ 0 & 0 & r & 0 & 0 & -1 \\ 0 & 0 & 0 & r & 0 & -1 \\ 0 & 0 & 0 & 0 & r & -1 \\ 0 & 0 & 0 & 0 & 0 & r-1 \end{bmatrix} \right| = r^6(r-1)$$

Then, solving for r in $r^6(r-1)$,

gives $r = 0, 0, 0, 0, 0, 1$. Therefore, the method is zero stable [16].

Dahlquist's theorem states that, the new method is convergent and consistency and zero-stability are analyzed and fulfilled.

3.4   Convergence

Theorem 3.1
Consistency and zero-stability are both required and sufficient conditions for a linear multistep method to be convergent. Therefore, the new method is convergent since it is consistent and zero-stable [15].

3.5   Region of Absolute Stability

The boundary locus method is used to generate the new method's stability polynomial [15]. The polynomial is defined as

$$\left.\begin{aligned}\bar{h}(w) = \left(-\frac{1}{5103}w^5 + \frac{1}{5103}w^6\right)h^6 + \left(-\frac{7}{2430}w^5 - \frac{7}{2430}w^6\right)h^5 + \left(-\frac{29}{1215}w^5 + \frac{29}{1215}w^6\right)h^4 \\ + \left(-\frac{7}{54}w^5 - \frac{7}{54}w^6\right)h^3 + \left(-\frac{25}{54}w^5 + \frac{25}{54}w^6\right)h^2 + \left(w^5 + w^6\right)h + w^5 + w^6\end{aligned}\right\} \quad (3.2)$$

The polynomial is used to plot the region as
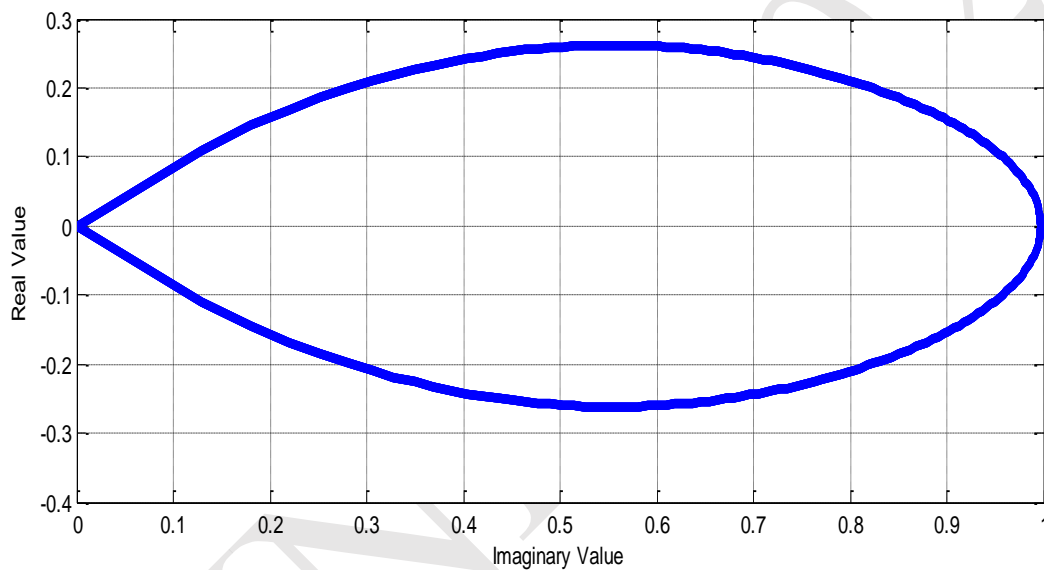
Fig. 3.1: Showing the region of stability of new method.

4   Results and Discussions

This section presents and discusses the results derived from various numerical examples. Additionally, the effectiveness of the proposed method is evaluated using four real-world problems, including the Malthusian Growth Model, the Prothero-Robinson equation, and other highly stiff oscillatory differential equations. For each case, the approximate solutions are compared to numerical benchmarks, and the absolute errors from the new method are contrasted with those from existing approaches to assess its accuracy and performance.

4.2   Numerical Examples

To evaluate the effectiveness of the developed methods, we present several numerical examples, including the following five cases **Example 4.1: Malthus Growth Model**

The Malthusian growth model, introduced by British economist Thomas Robert Malthus, is a population growth theory that highlights the potential for exponential population increase and its impact on resource availability. Malthus first articulated this theory in his 1798 work, *An Essay on the Principle of Population.* The model suggests that populations grow exponentially when resources are plentiful, leading to a scenario where the population size can double at a consistent rate over time, assuming no limiting factors. In contrast, Malthus argued that food supply increases arithmetically, by a fixed amount each period, resulting in a mismatch between population growth and resource

availability. According to Malthus, this imbalance ultimately leads to natural checks such as famine, war, or disease, which reduce the population. (Oluwaseun and Zurni (2022).

The Malthusian growth model can be described using a simple differential equation:

$$\frac{dy}{dx} = kp, \, x \in [0,1], \tag{4.1}$$

with the exact solution given by

$$y(x) = 100\exp(0.250679566129x) \tag{4.2}$$

Initial condition $y(0) = 100$ with $k = 0.250679566129$ and $h = 0.1$

Source: [7, 8].

Example 4.2: (**Prothero-Robinson Equation**)

Take into account the Prothero-Robinson oscillatory differential equation, which has been addressed by [16, 17], formulated as follows:

$$y' = \Phi(y - \sin x) - y, \, \Phi = -1, \, y(0) = 0 \tag{4.3}$$

Which has the exact solution as

$$y(x) = \sin x \tag{4.4}$$

Example 4.3: Consider the differential equation

$$\frac{du}{dv} = -\sin(v) - 200(u - \cos(v)), \, h = 0.01, \, u(0) = 0 \tag{4.5}$$

with the exact solution

$$u(v) = \cos(v) - e^{-200v} \tag{4.6}$$

Source: [17, 18]

Example 4.4: Consider the oscillatory differential equation

$$\frac{du}{dv} = -10(u - 1)^2, \, h = 0.01, \, u(0) = 2 \tag{4.7}$$

with the exact solution

$$u(v) = 1 + \frac{1}{1 + 10v} \tag{4.8}$$

Source: [18, 19]

Example 4.5: Consider the Highly stiff oscillatory differential equation

$$\frac{du}{dv} = -\psi u, \, h = 0.1, \, u(0) = \psi = 1 \tag{4.9}$$

with the exact solution

$$u(v) = \exp(-v) \tag{4.10}$$

Source: [20, 21]]

Table 4.1: The results of example 4.1 with [7, 8]

x	Exact Solution	Computed Solution	Absolute Errors	Error in [7]	Error in [8]
0.100	102.53847998347329794000	102.53847998347329790000	4.0000(-17)	1.6677(-08)	0.0000(00)

0.200	105.14139877321154182000	105.14139877321154182000	0.0000(00)	4.4003(-10)	0.0000(00)
0.300	107.81039213541335645000	107.81039213541335642000	3.0000(-17)	1.7117(-08)	0.0000(00)
0.400	110.54713735987489512000	110.54713735987489512000	0.0000(00)	8.8005(-10)	0.0000(00)
0.500	113.35335431405805132000	113.35335431405805129000	3.0000(-17)	1.7557(-08)	1.4211(-14)
0.600	116.23080652391598100000	116.23080652391598099000	1.0000(-17)	1.3201(-09)	1.4211(-14)
0.700	119.18130228215516429000	119.18130228215516425000	4.0000(-17)	1.7997(-08)	1.4211(-14)
0.800	122.20669578463047796000	122.20669578463047795000	1.0000(-17)	1.7601(-09)	0.0000(00)
0.900	125.30888829558742918000	125.30888829558742917000	1.0000(-17)	1.8437(-08)	1.4211(-14)
1.000	128.48982934248383035000	128.48982934248383034000	1.0000(-17)	2.2001(-09)	0.0000(00)

Table 4.2: The results of application problem 4.2 with [16, 17]

x	Exact Solution	Computed Solution	Absolute Errors	Error in [16]	Error in [17]
0.100	0.09983341664682815231	0.09983341664682691151	1.2408(-15)	1.4530(-11)	1.3422(-11)
0.200	0.19866933079506121546	0.19866933079506177666	5.6120(-16)	1.6211(-11)	2.1464(-11)
0.300	0.29552020666133957511	0.29552020666133611456	3.4606(-15)	2.1310(-11)	3.2359(-11)
0.400	0.38941834230865049167	0.38941834230865202176	1.5301(-15)	1.3799(-11)	4.1877(-11)
0.500	0.47942553860420300027	0.47942553860419784705	5.1532(-15)	2.7441(-11)	4.6377(-11)
0.600	0.56464247339503535720	0.56464247339503814732	2.7901(-15)	1.1114(-11)	5.3368(-11)
0.700	0.64421768723769105367	0.64421768723768473182	6.3219(-15)	2.8657(-11)	5.8936(-11)
0.800	0.71735609089952276163	0.71735609089952698884	4.2272(-15)	1.9218(-10)	6.0221(-11)
0.900	0.78332690962748338846	0.78332690962747641090	6.9776(-15)	1.2392(-10)	6.3342(-11)
1.000	0.84147098480789650665	0.84147098480790223848	5.7318(-15)	1.4711(-10)	6.5059(-11)

Table 4.3: The results of application problem 4.3 with [17, 18]

x	Exact Solution	Computed Solution	Absolute Errors	Error in [17]	Error in [18]
0.001	0.18126874692477177712	0.18126874692205980800	2.7120(-12)	6.5812(-06)	3.7249(-10)
0.002	0.32967795396412439246	0.32967795396502736584	9.0297(-13)	2.9379(-06)	5.2169(-10)
0.003	0.45118386391042716158	0.45118386390934856636	1.0786(-12)	9.3961(-05)	6.7870(-10)
0.004	0.55066303589223450724	0.55066303589344506955	1.2106(-12)	1.1305(-05)	7.6010(-10)
0.005	0.63210805885482676508	0.63210805885459932337	2.2744(-12)	7.9107(-06)	7.4126(-10)
0.006	0.69878778814058064233	0.69878778814179783856	1.2172(-12)	1.0313(-05)	7.4495(-10)
0.007	0.75337853615825529977	0.75337853615843502633	1.7973(-13)	1.0426(-05)	7.2211(-10)
0.008	0.79807148217492301264	0.79807148217601089409	1.0879(-12)	7.7981(-05)	6.5649(-10)
0.009	0.83466061205144457875	0.83466061205178772359	3.4315(-13)	8.4900(-05)	6.1326(-10)
0.01	0.86461471717914105002	0.86461471718005258589	9.1150(-13)	8.0388(-05)	5.6367(-10)

Table 4.4: The results of application problem 4.4 with [18, 19]

x	Exact Solution	Computed Solution	Absolute Errors	Error in [18]	Error in [19]
0.001	1.90909090884750640830	1.90909090889090909090	4.3403(-11)	2.4025(-08)	1.0700(-05)
0.002	1.83333333337241953740	1.83333333333333333330	3.9086(-11)	3.1560(-08)	2.3800(-05)
0.003	1.76923076920944483900	1.76923076923076923080	2.1324(-11)	3.2631(-08)	4.5100(-05)
0.004	1.71428571432193859870	1.71428571428571428570	3.6224(-11)	3.1192(-08)	6.2000(-04)
0.005	1.66666666668304290430	1.66666666666666666670	1.6376(-11)	2.8877(-08)	8.8400(-04)
0.006	1.62500000002955801560	1.62500000000000000000	2.9558(-11)	2.6370(-08)	1.0300(-03)
0.007	1.58823529413888054590	1.58823529411764705880	2.1234(-11)	2.3953(-08)	1.2700(-03)
0.008	1.55555555557943834040	1.55555555555555555560	2.3883(-11)	2.1734(-08)	1.5300(-03)
0.009	1.52631578949329163390	1.52631578947368421050	1.9607(-11)	1.9740(-08)	1.7500(-03)
0.010	1.50000000001952055900	1.50000000000000000000	1.9521(-11)	1.7969(-08)	1.8100(-03)

Table 4.5: The results of application problem 4.5 with [20, 21]

x	Exact Solution	Computed Solution	Absolute Errors	Error in [20]	Error in [21]
0.100	0.90483741803595957316	0.90483741803596084590	1.2727(-15)	9.0730(-12)	5.0000(-10)
0.200	0.81873075307798185867	0.81873075307798400161	2.1429(-15)	1.1768(-11)	5.0000(-10)

0.300	0.74081822068171786607	0.74081822068170938478	8.4813(-15)	2.3144(-11)	8.0000(-10)
0.400	0.67032004603563930074	0.67032004603564280973	3.5090(-15)	2.8440(-11)	7.0000(-10)
0.500	0.60653065971263342360	0.60653065971262806724	5.3564(-15)	3.1815(-11)	1.1000(-09)
0.600	0.54881163609402643263	0.54881163609403074200	4.3094(-15)	3.4927(-11)	1.1000(-09)
0.700	0.49658530379140951470	0.49658530379140642905	3.0857(-15)	3.6582e-11	1.1000(-09)
0.800	0.44932896411722159143	0.44932896411722629572	4.7043(-15)	3.8127(-11)	1.0000e-09
0.900	0.40656965974059911188	0.40656965974059764972	1.4622(-15)	3.8576(-11)	1.0000e-09
1.000	0.36787944117144232160	0.36787944117144713602	4.8144(-15)	3.9020(-11)	1.0000(-09)

4.3   Discussion and conclusion

This study introduces the use power series polynomial to derive the new method for solving various real-life problems in form of first-order stiff initial value problems. The new method were focused on their basic properties such as order, error constant, consistency, zero-stability and stability regions. The methods were applied to real-life problems, and results from tables 4.1 to 4.5. In this study, we have applied the new method on five numerical examples. Example 4.1 is the Malthus growth model and the results are presented in Table 4.1. These results are compared with those of [7, 8]. It is evident that the new method perform better than the methods proposed by [7, 8]. Example 4.2 involves the Prothero differential equation, which was analyzed using the new method. The comparisons of the results are shown in Table 4.2, alongside the solutions provided by [16, 17]. According to Table 4.2, the new method exhibit better convergence than the methods of [16, 17]. When solving the oscillatory differential equation in Example 4.3, the new method demonstrates faster convergence compared to the existing methods of [17, 18] for similar examples. For the oscillatory differential equation in Example 4.4, the new method outperform the methods of [18, 19] when solving similar examples, as shown in Table 4.4. Finally, Example 4.5 deals with another oscillatory differential equation. The results of solving Example 4.5 using the methods of [20, 21] are displayed in Table 4.5.

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Appendix

$$\psi_{01}, \psi_{02}, \psi_{03}, \psi_{04}, \psi_{05}, \psi_{06}, \psi_{07} = -\frac{19087h}{181440}, -\frac{2713h}{7560}, \frac{15487h}{60580}, -\frac{586h}{2835}, \frac{6737h}{60480}, -\frac{263h}{7560}, \frac{863h}{181440}$$

$$\psi_{11}, \psi_{12}, \psi_{13}, \psi_{14}, \psi_{15}, \psi_{16}, \psi_{17} = -\frac{863h}{181440}, -\frac{349h}{2520}, \frac{5221h}{20160}, -\frac{254}{2835}, \frac{811h}{20160}, -\frac{29h}{2520}, \frac{271h}{181440}$$

$$\psi_{21}, \psi_{22}, \psi_{23}, \psi_{24}, \psi_{25}, \psi_{26}, \psi_{27} = -\frac{37h}{11340}, \frac{233h}{1890}, \frac{1621h}{3780}, \frac{322h}{2835}, \frac{11h}{3780}, -\frac{h}{378}, \frac{h}{2268}$$

$$\psi_{31}, \psi_{32}, \psi_{33}, \psi_{34}, \psi_{35}, \psi_{36}, \psi_{37} = -\frac{29h}{6720}, \frac{37h}{280}, \frac{877h}{2240}, \frac{34h}{105}, \frac{387h}{2240}, -\frac{h}{56}, \frac{13h}{6720}$$

$$\psi_{41}, \psi_{42}, \psi_{43}, \psi_{44}, \psi_{45}, \psi_{46}, \psi_{47} = -\frac{8h}{2835}, \frac{38h}{315}, \frac{136h}{315}, \frac{664h}{2835}, \frac{136h}{315}, -\frac{38h}{315}, -\frac{8h}{2835}$$

$$\psi_{51}, \psi_{52}, \psi_{53}, \psi_{54}, \psi_{55}, \psi_{56}, \psi_{57} = -\frac{275h}{36288}, \frac{235h}{1512}, \frac{3875h}{12096}, \frac{250h}{567}, \frac{2125h}{12096}, -\frac{725h}{1512}, -\frac{3715h}{36288}$$

$$\Omega_{11},\Omega_{12},\Omega_{13},\Omega_{14},\Omega_{15},\Omega_{16},\Omega_{17} = \frac{19087h}{181440}, \frac{2713h}{7560}, -\frac{15487h}{60480}, \frac{586h}{2835}, -\frac{6737h}{60480}, \frac{263h}{7560}, -\frac{863h}{2835}$$

$$\Omega_{21},\Omega_{22},\Omega_{23},\Omega_{24},\Omega_{25},\Omega_{26},\Omega_{27} = \frac{1139h}{11340}, \frac{94h}{189}, \frac{11h}{3780}, \frac{332h}{2835}, -\frac{269h}{3780}, \frac{22h}{945}, -\frac{37h}{11340}$$

$$\Omega_{31},\Omega_{32},\Omega_{33},\Omega_{34},\Omega_{35},\Omega_{36},\Omega_{37} = \frac{137h}{1344}, \frac{27h}{56}, \frac{387h}{2240}, \frac{34h}{105}, -\frac{243h}{2240}, \frac{9h}{280}, -\frac{29h}{6720}$$

$$\Omega_{41},\Omega_{42},\Omega_{43},\Omega_{44},\Omega_{45},\Omega_{46},\Omega_{47} = \frac{286h}{2835}, \frac{464h}{945}, \frac{128h}{945}, \frac{1504h}{2835}, \frac{58h}{945}, \frac{16h}{945}, -\frac{8h}{2835}$$

$$\Omega_{51},\Omega_{52},\Omega_{53},\Omega_{54},\Omega_{55},\Omega_{56},\Omega_{57} = \frac{3715h}{36288}, \frac{725h}{1512}, \frac{2125h}{12096}, \frac{250h}{567}, \frac{3875h}{12096}, \frac{235h}{1512}, -\frac{275h}{3628}$$

$$\Omega_{61},\Omega_{62},\Omega_{63},\Omega_{64},\Omega_{65},\Omega_{66},\Omega_{67} = \frac{41h}{420}, \frac{18h}{35}, \frac{9h}{140}, \frac{68h}{105}, \frac{9h}{140}, \frac{18h}{35}, -\frac{41h}{420}$$

Optimization of Distributed Energy Resources and Incentive Based Demand Response for Emission Reduction in Microgrid Systems

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Abstract. Fossil fuel dependency in power generation, though essential for meeting energy needs, leads to harmful greenhouse gas emissions. This paper explores how integrating distributed energy resources (DERs) with incentive based demand response (IBDR) strategies in microgrids can help reduce emissions, offering a sustainable solution for cleaner energy systems. The first objective is to minimize emissions and grid operating costs by integrating DERs and applying IBDR strategies to reduce loads during peak periods, thereby enhancing grid efficiency. The second objective is to maximize grid utilities' profits while minimizing emission costs. The formulated model facilitates optimal load management, reducing operational costs and emissions-related expenses within the microgrid. The optimization of the proposed microgrid is framed as a quadratic programming problem over a 24-hour scheduling period, which was successfully solved. Simulation results validate the effectiveness and efficiency of the model, demonstrating its operational applicability in achieving emission reduction while maintaining system reliability and cost-effectiveness.

Keywords: Distributed energy resources, Incentive-based demand response,Emission reduction,Multi-objective optimization

1 Introduction

Globally, DERs are among the most effective technologies for achieving zero emissions. Microgrids refer to the integration of DERs, such as wind and photovoltaics, along with other renewable energy sources like biomass, geothermal, and hydropower, into the existing grid, as shown in Figure 1. A microgrid is a scheme that combines traditional and clean energy sources on a small volume, combining the essential components of the power system to provide dependable operation from generation to load demand[1]. Microgrids are becoming more and more popular as a response to the problems caused by the unpredictable behavior of renewable energy sources and the varied demands of new electricity consumers, as cross sector decarbonization and electrification develop strength. One key advantage of microgrids is their flexibility, as they can operate either connected to the larger electricity grid or independently, ensuring a more resilient and adaptable energy distribution network[2]. The Asia-Pacific area and North America are home to the majority of the world's microgrids, with China accounting for the highest proportion of capacity in both regions. A semi annual tracker predicted that during the fourth quarter of 2017, there were approximately 1,869 micro grids with a total capacity of 20.7 gigawatts (GW) worldwide, despite the fact that there is no centralized registry for microgrids [3]. Over the past 13 years, the global installed capacity of DERs has seen significant growth, increasing from 73.745 GW and 220.019 GW to 713.970 GW and 733.276 GW, respectively [4]. It is projected that in the year 2050, variable renewable

energy is expected to constitute up over 60 percent of the world's electricity generation, half of this energy will come from photovoltaic (PV) solar power and half from the wind [5].
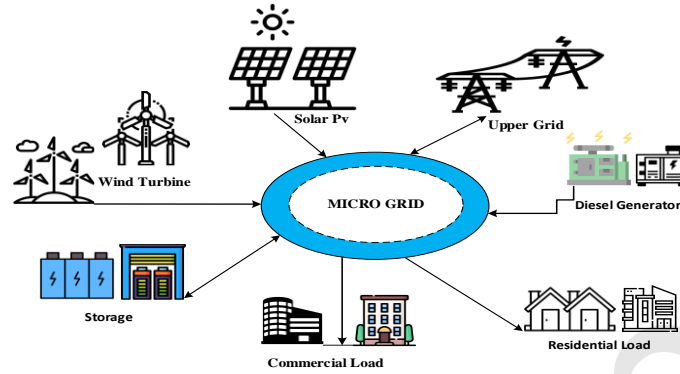
Fig. 1. Microgrid Architechcure

Demand Response, is one of the vital components of the smart grid, is an effective strategy for encouraging power consumers to adjust their energy usage pattern in response to price fluctuations or incentive signals. By modifying their consumption patterns, consumers on the demand side can contribute to balancing supply and demand within the power market, as well as alleviating system capacity constraints [6].

The first IBDR program was launched in 1968 by the electrical utility company Detroit Edison, the customers enrolled in price-based programs are exposed to pricing that change every day of the week and consumers are compensated based on the amount of load they curtail [7]. In 2008, in the U.S, 38,000 MW of possible peak load reductions was achieved through IBDR programs, and an additional 2,700 MW was achieved through price-based demand response schemes [8]. The work of [9],[10],[11] explores the ideal microgrid schedule that includes traditional generators, renewable energy sources, and incentive demand response model. Their objective is to attain an optimal financial situation by minimizing expenses related to trading and generators expense while also optimizing the microgrid's demand response program's profit without considering emissions reduction. The literature reviewed in this research primarily focuses on optimizing operational cost reductions and maximizing utility benefits through the implementation of incentive-based demand response (IBDR) programs.

This study addresses a gap in the existing literature by focusing on minimizing emissions costs through the combined use of IBDR and DERs, an area often overlooked. It introduces a flexible dispatch strategy, where DERs and IBDR are coordinated to meet both grid demands and emission reduction goals, thereby minimizing emissions while maintaining grid stability and promoting environmental sustainability.

2 Modelling of the Proposed System

2.1 Microgrid model

The integration of DERs into the microgrid is examined, along with possible modeling techniques for solar photovoltaic cells, micro wind turbines, diesel engines, and upper grid connections in microgrids.

The specific hourly energy generation of a photovoltaic (PV) array is affected by several key factors and can be quantified using the formula provided in equation (1) and mathematically expressed as[12]:

$$H_{pv} = n_{pv} \times A_c \times Ipv_t \tag{1}$$

Where, H_{pv} represents the hourly power output from the PV generator, n_{pv} represents the efficiency of the solar array, Ipv_t is the hourly solar irradiation received by the PV array, and A_c is the total surface area of the PV system.

A wind turbine's output power is determined by the direction and velocity of the wind. The hourly energy generated based on the hourly wind speed is expressed as [13].

$$H_{wt} = 0.5 \times \eta_w \times \rho_{air} \times C_p \times A \times V^3 \tag{2}$$

Where, H_{wt} is the hourly power generated by wind generator, V is the hub height , η_w is the efficiency of the wind generator, ρ_{air} is the amount of air, A is the area encompassed by the sweep of the rotor, and C_p is the conversion power ratio of the wind turbine.

Diesel generators in a grid-connected microgrid usually operate at nominal power. Any excess power produced can be efficiently managed by either storing it in batteries for later use or by covering the portion of the load demand that cannot be met due to the fluctuations of DERs and mathematically expressed as[14]:

$$P_{\min}^{diesel} \cdot U_I(t) \le P_{(t)}^{diesel} \le P_{\max}^{diesel} \cdot U_I(t) \tag{3}$$

$$U_I(t) = \begin{cases} 1 & p_{(t)}^{diesel} > 0 \\ 0 & p_{(t)}^{diesel} \le 0 \end{cases} \tag{4}$$

$$C_{diesel}(P_{I,t}) = a_I P_{I,t}^2 + b_I p_{I,t} \tag{5}$$

Where, $P_{\min}^{diesel}$ and $P_{\max}^{diesel}$ represents the minimum and maximum power output produced, $U_I(t)$ is a binary variable indicating the generator's operational status, where it is either ON or OFF. Equation (5) represents the generators cost function, Where, a_I , b_I are the fuel cost parameters of diesel generators, $P_{I,t}$ is the diesel engine electricity output during a specified period.

Diesel generators produced harmful gasses such as, carbon dioxide (CO_2), sulfur oxides (SO_2) and nitrogen oxides (NO_X). Daily Emission Cost (DEC) can be employed to measure and analyze the cost of emissions from conventional diesel generators. A diesel generator's DEC can be expressed as [14].

$$DEC = Emc_I \times \sum_{I=1}^{n}[Gp_{diesel}] \tag{6}$$

Where, Emc_I represents emission cost generated, Gp_{diesel} is the generated energy from the diesel generator. The total annual emission cost and interest rate can be expressed as:

$$Emc_I = Cem_I(1+fp)^{P_{proj}} \tag{7}$$

$$Cem_I = (a_i EF_{CO_{2,I}} P_I + a_j EF_{SO_{2,I}} P_I + a_k EF_{NO_{x,I}} P_I) \tag{8}$$

Where, $a_i P_I, a_j P_I, a_k P_I$, represents the emission externality costs (\$/kg) for each pollutant, Cem_I is the emission cost generated by each unit of generator. $EF_{CO_{2,I}}$, $EF_{SO_{2,I}}$, $EF_{NO_{x,I}}$, denotes the conventional generator unit I, CO_2, SO_2 and NO_x denotes emission factors in (kg/kW h) .

In this study, an electricity market model is established to enable the exchange of power between the upper grid and the microgrid. The transferable electricity at time t, connecting the microgrid with the main grid, is described in equation (9).

$$C_r(E_{transfer(t)}) = \begin{cases} (E_{transfer(t)})(\gamma_t) & E_{transfer_{(t)}} > 0 \\ 0 & E_{transfer(t)} = 0 \\ (E_{transfer(t)})(-\gamma_t) & E_{transfer(t)} < 0 \end{cases} \tag{9}$$

Where, $C_r(E_{transfer(t)})$ is the cost of power from the main grid to the microgrid, and (γ_t) denotes the charging cost for all power consumed per hour.

2.2 INCENTIVE BASED DEMAND RESPONSE MODEL

An IBDR model is used in this study in other adapts the electricity usage behavior of the microgrid users to the availability of energy.

The IBDR objective is given as :

$$\sum_{t=1}^{H=24} \sum_{i=1}^{Tn} [x_{i,t} \lambda_{i,t} - M_{(cp)i,t}] \tag{10}$$

Subject to the following constraints:

$$\sum_{t=1}^{H=24} [M_{(cp)i,t} - [(k_1 x_{i,t}^2) + (k_{2,i} x_{i,t}) - (k_{2,t} x_{i,t} \theta_i)]] \tag{11}$$

$$\leq \sum_{t=1}^{H=24} [M_{(cp)[i-1],t} - [(k_{1,[i-1]} x_{i,t}^2) + (k_{2,[i-1]} x_{i,t}) - (k_{2,[i-1]} x_{[i-1],t} \theta_{[i-1]})]] \tag{12}$$

$$\sum_{t=1}^{H=24} \sum_{i=1}^{Tn} M_{(cp)i,t} \leq Ov_{bdg} \tag{13}$$

$$\sum_{t=1}^{H=24} x_{i,t} \leq Dda_{max} \tag{14}$$

Where, $M_{(cp)}$ is the monetary payment given to the consumers for load reductions, x represents the amount of power in (\$/kWh) that the consumer is willing to curtail, k_1, k_2, denotes the cost coefficient functions, λ represents the cost incurred by the utility for failing to supply power to a specific point on the grid, θ denotes the customer's willingness to participate, expressed as a value between 0 and 1, Dda_{max} represents the maximum daily limit for power supply interruptions that a customer is willing to accept, Ov_{bdg} is the total cost from the utility's budget for the entire scheduling period, and H, t, i and T_n are integer variables.

The overall objective of the IBDR model, DERs(solar and wind energy), conventional diesel generators, emission cost and a connection to the power grid is expressed as:

$$Obj = \min \left[\begin{array}{c} (J_{w1}) \left\{ = \sum_{I=1}^{Td} \sum_{t=1}^{t=24} C_{diesel}(P_{I,t}) + Emc_I \times Gp_{diesel_{I,t}} + \sum_{t=1}^{t=24} C_r(E_{transfer(t)}) \right\} \\ + (J_{w2}) \left\{ \sum_{t=1}^{H=24} \sum_{i=1}^{Tn} [x_{i,t} \lambda_{i,t} - M_{(cp)i,t}] \right\} \end{array} \right]$$

(15)Where,the weighting factors J_{w1} and J_{w2} balance two key objectives: minimizing generator fuel costs to reduce emissions and energy exchange costs, and maximizing the utility's benefit function.

The overall objective is ubject to the following consttraints:

$$\sum_{I=1}^{T_d} (P_{I,t}) + EH_{pv(t)} + EH_{wt(t)} + E_{transfer(t)} = Ld - \sum_{i=1}^{Tn} x_{i,t} \tag{16}$$

$$P_{I,min} \leq P_{I,t} \leq P_{I,max} \tag{17}$$

$$-MaxR_{dw_I} \leq P_{I,t+1} - P_{I,t} \leq MaxR_{up_I} \tag{18}$$

$$0 \leq EH_{pv(t)} \leq H_{pv(t)} \tag{19}$$

$$0 \leq EH_{wt(t)} \leq H_{wt(t)} \tag{20}$$

$$-E_{transfer(max)} \leq E_{transfer(t)} \leq E_{transfer(max)} \tag{21}$$

Where, equation (16) denotes the overall constraints for diesel,emission,wind,solar, and load demand. Equation (17) and (18) explains the constraints of the diesel generators, and their ramp rates and limit, equation (19) and (20) denotes the photovoltaic solar and wind constraints, and equation (21) denotes the upper grid transfer constraints.

3   Case Study

The economic standard for assessing the damage caused by each kilogram of greenhouse gases emitted per hour is evaluated using the emission externality cost, detailed in Table 1. Figure 2 presents the solar irradiation and wind data for the selected site, based on [15]. Figure 3 shows the load demand, which reflects the amount of electricity required by businesses and consumers at any given time, based on [9]. All relevant parameters were carefully considered to simulate a realistic scenario.

Table 1. Diesel emission factors and cost [14]

Emission Type	Cost of Emission ($/Kg)	Diesel Emission Factor (Kg/kW h)
CO_2	0.017	0.6569395
NO_X	1.086	0.0066911
SO_2	1.8	0.0003595
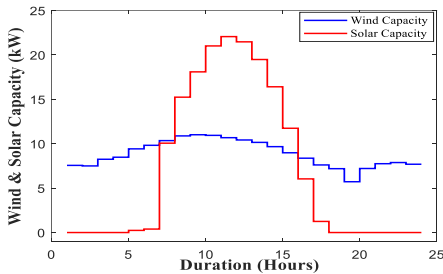
Fig. 2. *Solar and Wind curves*
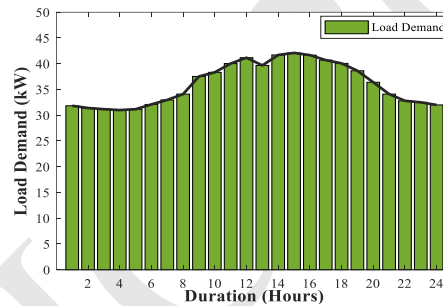
Fig. 3. *Load Demand*

Figure 2 shows the power output curves of the solar and wind generators. The solar generator can produce a maximum of 22.06 kW and a minimum of 0.24 kW. Solar energy generation is limited to daytime hours due to its dependence on solar radiation. The wind generator has a minimum output of 5.72 kW and a maximum output of 11.01 kW. The comprehensive power curve in Figure 2 illustrates the fluctuations in output from DERs.

3.1 RESULTS

A systematic analysis was carried out to assess the model's effectiveness in reducing emissions and operational costs. The problem is formulated as a quadratic multi-objective optimization problem using the YALMIP toolbox in MATLAB and solved with the GUROBI solver. A 24-hour scheduling framework is employed to carefully manage the dynamic exchange of electricity between a microgrid and the larger power grid. Figure 4 shows a comprehensive power exchange between the upper grid and microgrid within the 24 hours scheduling period, it can be seen that the maximum power transmitted back to the upper grid was 4 kW, while the peak power received from the upper grid was only 2.81 kW. This indicates that the microgrid can operate independently. Furthermore, the successful application of incentive-based strategies demonstrates that the microgrid is capable of satisfying its own demand without heavily depending on the upper grid.
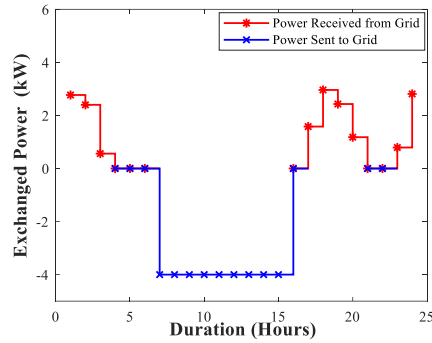
Fig. 4. Power transfer between grid and upper grid

For peak load reduction, for their flexibility, three consumers have consented to take part in a controlled load reduction program in exchange for a financial reward, receiving a monetary reward in exchange for their flexibility. The first customer is ranked highest and agrees to curtail a total of 38 kW within the scheduling period, followed by the third customer, who agrees to curtail 35 kW, and the second customer with the least at 32 kW. A flat-rate reimbursement for load curtailment was applied at \$1.43 per kW. Figure 5 illustrates the total load curtailment achieved by each customer and the financial rewards they received for their participation during the scheduling period.
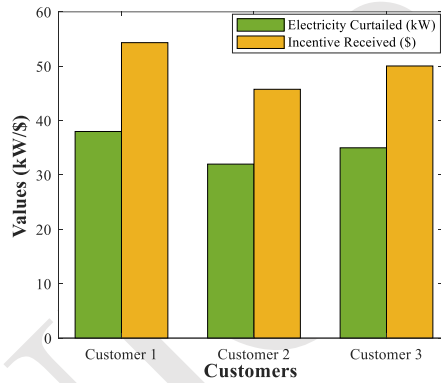
Fig. 5. Total load curtailed and the corresponding incentives received by each customer

The insights from Figure 5 illustrate the operational framework of the incentive-based programs, where the willingness of customers to curtail load significantly influences their ranking and the incentives they receive. This pattern underscores the program's goal to motivate higher energy saving actions among consumers, effectively managing demand and promoting energy efficiency on a broader scale.

The model was analyzed using an equalized weight factor, giving equal priority to two objectives: minimizing emissions and operating costs, and maximizing utility benefits. By assigning equal weight to both, equilibrium between these objectives was achieved. A lower weight reduces the cost of the first objective, while a higher weight increases it, and vice versa.

Figure 6 shows the total emissions produced and the costs incurred by each segment over a 24-hour scheduling period.
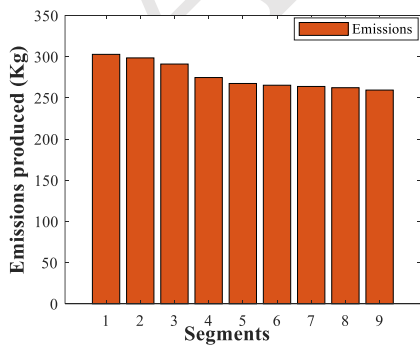
Fig. 7. Emission produced over the segments
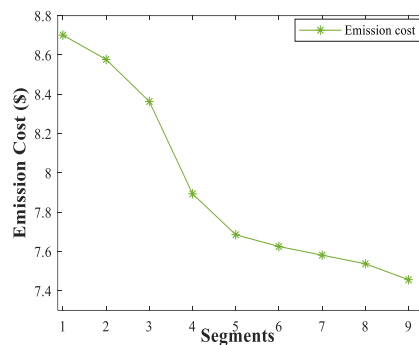
Fig. 6. Cost incurred

 The emissions are calculated based on the diesel generator externality factors provided in Table 1. Figure 6 presents the total emissions produced. The highest emissions were observed in segment 1. This is because segment 1 prioritized utility maximization over emission reduction, resulting in almost all diesel generators being operational. In segment 5, equal weight was given to both objectives reducing emissions and maximizing utility. The lowest emissions occurred in segment 9, because emission reduction is prioritized fully over the other objective.

Figure 7 displays the cost curve representing the total emissions costs incurred from all greenhouse gases. The curve indicates a downward trend, highlighting a reduction in costs from higher to lower levels. Segment 1 incurs the highest cost, while segment 5, which was utilized in this study, has an average cost . This segment was chosen due to its relatively lower cost compared to earlier segments, and equal priority was given to both objectives by selecting segment 5.

Table 2. Summary of the Model

Power Sources	Energy (kW)
Conventional power produced	403.6584
Power produced by DERS	375.00
Power received from upper grid	17.48148
Power sent to upper grid	-36
Power curtailed/Shifted	105
Total load demand	865.14

Table 2 shows that the microgrid, with a total load demand of 865.14 kW, draws 375 kW from DERs and engages customers in demand response programs to curtail 105 kW. Additionally, it receives 17 kW from the upper grid. As a result, 46.6% of the total demand is met by conventional power sources, while 53.34% is supplied by clean energy from DERs and demand response load reduction strategies. Furthermore, the microgrid exports 36 kW back to the upper grid, maximizing its utility benefits.

4 CONCLUSION

In this study, a technique for reducing emissions through an IBDR coupled with DERs is applied. This approach successfully reduced the total consumer load during the scheduling period. Diesel generators operated at 46.6% of the total microgrid demand, resulting in significantly lower operational costs. Financially, the model proved beneficial as it generated revenue from selling electricity, while the cost of purchasing power from the upper grid was minimal. This indicates that the microgrid can operate independently from the upper grid. In --terms of environmental impact, the model incurred lower emission cost as shown in Figure 7, which shows that there is a high penetration of clean energy sources and load management strategies. With over 50% of the microgrids demand met by DERs and load management strategies, the model aligns with the study's goal of reducing emissions and promoting environmental sustainability. However, expanding renewable energy sources and energy storage, along with integrating a carbon trading mechanism, is recommended to further enhance microgrid operations. This would offer financial flexibility through the trading of carbon credits and help reduce emissions to the lowest possible levels.

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Gated Recurrent Unit Integrated Lee-Carter Model for Overall Mortality Modelling

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Abstract

Mortality rate has traditionally been used as an essential health indicator for assessing population well-being and has consistently gained prominence in the Millennium Development Goals (MDGs) and Sustainable Development Goals (SDGs). Over the past decades, new models for mortality modeling have been developed. A pioneering and most influential model among others is the Lee-Carter model developed by Lee and Carter in 1992. Since its development, the model has undergone extensive review, and other variants with various structures suggested. While the model's effectiveness has been evaluated in various scenarios, its capacity to precisely handle non-linearity and long-term dependence in the mortality index over time has not been thoroughly examined. The Lee-Carter (LC) model's conventional approach exhibits evident limitations in predicting future mortality patterns. Therefore, this study focused on using a Gated recurrent unit integrated LC model to correct some of the shortfalls of the traditional LC model. Simulated data from Weibull and Gompertz distributions were used. Using the performance metrics (RMSE, MAE and MAPE) LC-GRU model showed promising results in handling the non-linearity and long-term dependence inherent in mortality data.

Keywords: Lee-Carter model, ARIMA, Gated recurrent unit, Singular value decomposition, Mortality rate.

1 Introduction

In actuarial science and demography, mortality predictions have a long history. Mortality estimates are utilized by actuaries for pension annuities, life insurance reserves, cash flow forecasts, and population projections. Government agencies use mortality forecasts to help them make decisions about funding for retirement income, social security, and healthcare (Oeppen and Vaupel, 2002). Having a clear understanding of future mortality and longevity risk is crucial for individuals in actuarial science and government authorities alike. While advancements in longevity lead to improved well-being and longer productive lives for many individuals, they also pose challenges for pension systems. The rising life expectancy increases the financial burden on pension systems, potentially putting the long-term creditworthiness of financial institutions at risk due to unforeseen and growing future obligations. Moreover, the increase in mortality rates among older age groups also impacts public health expenditures when unhealthy life expectancies is prolonged (Blake *et al.,* 2014). Adult mortality has received little attention over the years, especially in emerging nations like Nigeria, while infant and child mortality have received significant attention.

The workforce of any country is a crucial component of the adult population and should not be disregarded. Researchers place a high priority on predicting future mortality rates and life expectancy to gain valuable insights into future trends. To achieve this, numerous stochastic models have been devised for mortality forecasting, such as those proposed by McNown and Rogers (1989), Lee and Carter (1992), Alho (1990), Currie *et al.* (2004), Cairns *et al.* (2006), and Renshaw and Haberman (2006). The Lee-Carter model has a number of shortcomings despite its widespread acceptance and realistic performance, these includes the assumption of constant speed of change in mortality and that the time series behavior during the observed period cannot possibly reflect a fundamental property of mortality change over time (Lee, 2000).

In order to improve the predictive ability of the Lee-Carter model for prediction, this study employed artificial intelligence approaches. To predict future death rates, the research combined the Lee-Carter model with a Deep Recurrent Neural Network (DRNN) using a Gated recurrent unit (GRU) architecture called LC-GRU model. The

DRNN makes it possible to calculate mortality projections that are more consistent with the variability and nonlinear trends observed in mortality. More specifically, the DRNN is set up to handle lengthy data sequences, creating a memory that can hold onto important links between data. In this sense, the time series framework of the GRU enables the prediction of future mortality over time, taking into account the significant influence of the historical mortality pattern and accurately reproducing it in the trend that is predicted.

2 Materials and Methods

According to available studies by (Richmond and Roehner, 2021), mortality in infancy and childhood mostly follow the Weibull distribution, while mortality in adulthood and old age largely follows the Gompertz distribution. This study therefore simulates data on childhood deaths from the Weibull distribution and data on adult and old-age mortality from the Gompertz distribution.

2.1 LC-GRU Model

If we let the mortality data collected at times to be $g(1)$, $g(2), \ldots, g(J)$ then the LC-GRU model is given as:

$$\ln(m_{xg(t)}) = a_x + b_x(k_{g(t-1)}, k_{g(t-2)}, \ldots, k_{g(t-J)}) + \varepsilon_{xg(t)} \tag{1}$$

$$m_{xg(t)}^i = \exp(a_x + b_x(k_{g(t-1)}, k_{g(t-2)}, \ldots, k_{g(t-J)}) + \varepsilon_{xg(t)}) \tag{2}$$

i=infant, child, adult or old age mortality

$$\text{where } \varepsilon_{xg(t)} \square N(0, \sigma^2), \quad k_{g(t)} = f(k_{g(t-1)}, k_{g(t-2)}, \ldots, k_{g(t-J)}) + \varepsilon_{g(t)} \tag{3}$$

$k_{g(t)}$ is a GRU model that approximates a function f that links $k_{g(t)}$ to its time lags, and $j \in N$ represents the number

of time lags considered and ε_t is the error term.

$m_{xg(t)}$ represent segmented mortality that is infant mortality, adult mortality or old age mortality, respectively.

a_x is the average shape of the age parameter for segmented mortality.

b_x is the speed of change parameter for segmented mortality.

2.1.1 Assumptions of the LC-GRU Model

i.   It is not sensitive to the distribution assumed for the error term.
ii. It can handle both the linear and non-linear nature of mortality trends, thus adding confidence to extrapolations.
iii. Data size and accuracy of measurement are requisites for better results.

2.2 Parameter Estimation using Singular Value Decomposition

Bell and Monsell introduced the Singular Value Decomposition (SVD) in 1991. It is a technique for breaking a matrix into its constituent matrices, revealing several valuable and distinctive characteristics of the original matrix. The matrix is ideally broken down into some set of factors that are optimum based on some criteria (typically orthogonal or independent). Matrix A can be uniquely decomposed as:

$$A = UDV^T \tag{4}$$

Assume that A is a matrix of order $m \times n$. Then U is defined to be a $m \times m$ matrix, D to be a $m \times n$ matrix, and V to be a $n \times n$ matrix. Matrix D is a diagonal matrix. The elements along the diagonal of D are regarded as the singular values of the matrix A. The columns of U are regarded as the left-singular vectors. The right-singular vectors are the columns of V.

Since there are no provided regressors on the right side of the estimate, the Lee-Carter model cannot be fitted using conventional regression techniques. The estimators of a_x, b_x and k_t are denoted as $\hat{a}_x$, $\hat{b}_x$ and $\hat{k}_t$ accordingly. Firstly, let's define the $\hat{a}_x$ estimate as the averaging $\ln(\hat{m}_{x,t})$ over a period of time t:

$$\hat{a}_x = \frac{\sum \ln(m_{xt})}{n} \tag{5}$$

The parameters $\hat{b}_x$ and $\hat{k}_t$ are calculated by applying Singular Value Decomposition to the matrix A. where;

$$A = \ln m_{xt} - \hat{a}_x \tag{6}$$

That is;

$$\text{SVD(A)} = \text{ULV}^T \tag{7}$$

Where U represents the age component, L represents the singular values and V represents the time component.

2.3 Gated Recurrent Unit

The Gated Recurrent Unit (GRU) is another alternative method that reduces the number of gates while improving design complexity. It utilizes a mix of the cell state, hidden state, as well as an update gate that includes input and forgotten gates integrated into it (Van *et al.*, 2020). GRU is built to efficiently tackle the vanishing gradient problem, just like LSTM networks, and it has a gated mechanism to effectively capture dependencies on various time scales. There is a gate there that updates and resets. The gates in the GRU play a crucial role in determining what data needs to be stored for future predictions. The GRU module as presented by Cho *et al*. (2014) is given as
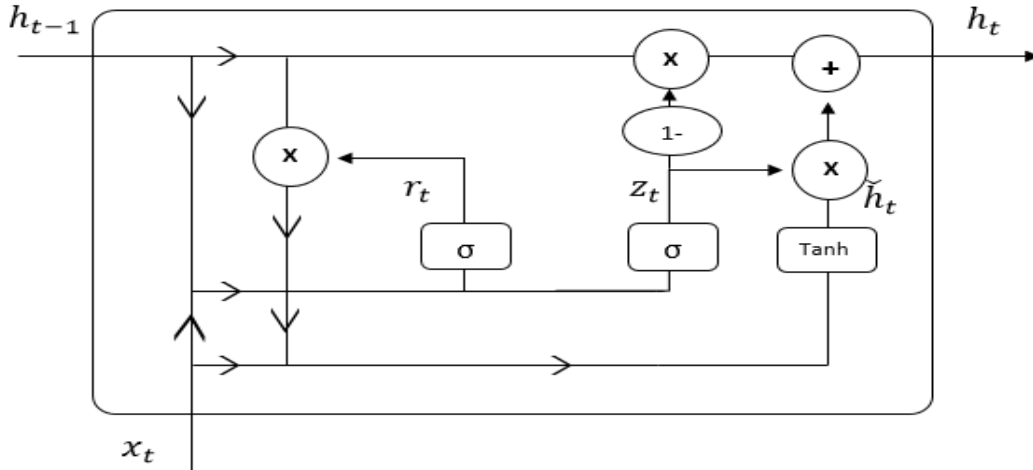
Figure 1. GRU Module Containing Interacting Layers

At each time stamp t, it takes an input x_t and a hidden state h_{t-1} from a preceding time stamp $t-1$. Later it outputs a new hidden state H_t which again passed to the next timestamp. Equation 8 shows the flow of information in the update gate, the update gate determines what past information to update, equation 9 represents the flow of information in the reset gate, and it determines what past information to forget. Equation 10 is the memory compartment; it holds all the memories of the network, while equation 11 represents the information to be moved forward to the next time step.

$$z_t = \sigma\left(W_z\left(h_{t-1}, x_t\right)\right) \tag{8}$$

$$r_t = \sigma\left(W_r\left(h_{t-1}, x_t\right)\right) \tag{9}$$

$$\tilde{h}_t = \sigma\left(W\left(r_t * h_{t-1}, x_t\right)\right) \tag{10}$$

$$h_t = \left(1 - z_t\right) * h_{t-1} + z_t * h_t \tag{11}$$

3. Results and Discussions

Here, we model the entire mortality profile using the traditional LC model and the LC-GRU model. Infant and child mortality data was simulated from the Weibull distribution while adult and elderly mortality data was simulated using the Gompertz distribution. SVD was used to estimate the model parameters, $\hat{a}_x$ the age profile, $\hat{b}_x$ the speed of change of mortality and $\hat{k}_t$ the mortality index.

Table 1. Estimates of a_x and b_x parameters

Age	$\hat{a}_x$	$\hat{b}_x$
0-1	-1.19200	0.23818
1-4	-1.29242	0.42841
5-9	-1.00494	-0.03407
10-14	-1.41808	-0.06639
15-19	-1.61412	-0.22277
20-24	-1.39533	-0.11996
25-29	-1.37016	0.19069
30-34	-0.93252	0.01035
35-39	-1.25936	-0.09889
40-44	-1.45198	-0.18301
45-49	-1.14766	0.12715
50-59	-1.76417	0.20008
60-64	-1.50513	0.06085
65-69	-1.17955	-0.09992
70-74	-1.10266	-0.03025
75-79	-2.08827	-0.16427
80-84	-1.71454	0.17716
85-89	-1.54349	0.15225
90-94	-1.31360	0.32028
95+	-1.62864	0.10139
	-1.34851	0.01273

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Table 2. Estimates of time index k_x parameter

$\hat{k}_t$
0.11577
2.12297
1.30991
0.51811
-0.22011
3.08496
-3.10477
2.25683
-5.42957
-0.77475
1.42280
-1.30214

Tables 1 and 2 show the parameter estimates using SVD for the overall mortality profile using a simulated data.

Table 3. Comparison between LC-ARIMA and LC-GRU

Mortality	RMSE	MAE	MAPE
LC-ARIMA	0.20318	0.15656	0.95844
LC-GRU	0.18164	0.14697	0.89160

Table 3 presents the performance evaluation metrics of M_x (mortality rate) using the traditional LC model and M_x using GRU integrated Lee-Carter (LC-GRU) model. The results show that the LC-GRU model is better than the traditional LC model in modelling the overall mortality profile for mortality data with varying rate of change in mortality b_x across different age groups.

4. Conclusion

The hyperparameters of the GRU model considered include: epoch size (100), activation function (Swish), initial learning rate (0.0001), and number of layers in the hidden state. The optimal hyperparameter values of the GRU model were first obtained and subsequently integrated into the LC model. The Swish AF was used to allow the network to effectively learn complex patterns in the data set. Error measures were used to validate the effectiveness of the developed model, which is a GRU-assisted LC model (LC-GRU model). The LC-GRU model was compared with the traditional LC model, it gives more accurate mortality forecasts than the traditional LC model approach using simulated data. Since the effectiveness of the LC-GRU model in its ability to handle nonlinearity and long-term dependence in mortality data has been validated over the traditional LC model, the study recommends using the LC-GRU model to forecast age-specific mortality because the model has corrected some of the LC model's identified limitations.

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Numerical Methods for Solving First-Order Nonlinear Differential Equations Using a Linear Block Approach

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Abstract

This study presents a new block hybrid method aimed at solving nonlinear first-order initial value problems (IVPs). Nonlinear IVPs often appear in complex systems involving phenomena such as population dynamics, fluid flow and chemical reactions. These problems are characterized by chaotic behavior, multiple solutions and sensitivity to initial conditions, making analytical solutions difficult to obtain. To address this challenge, the study develops a block hybrid method using a linear block approach. The method employs polynomial interpolation to derive a continuous scheme, which is then discretized to generate the block method. The method is analyzed to determine its properties, including consistency, zero-stability and convergence. The block method is found to have an order of seven and the corresponding error constant is computed to demonstrate its high accuracy. A stability function is derived to examine the method's behavior and the region of absolute stability is plotted to verify its performance for stiff equations. Numerical experiments are conducted to validate the method, with results compared to existing techniques. The new block hybrid method exhibits superior accuracy, efficiency and stability when applied to nonlinear first-order IVPs, outperforming traditional methods in terms of reduced error and computational effort. This method offers a valuable alternative for solving complex nonlinear differential equations.

Keywords: Block hybrid method, Convergence analysis, Linear block approach, Nonlinear first-order IVPs, Zero-stability.

1   Introduction

Mathematics plays a crucial role in addressing empirical problems across applied sciences and various other disciplines, especially when noise is introduced into deterministic models based on differential equations [1, 2]. Traditional nonlinear differential equations have been found insufficient and ineffective for managing complex systems that involve millions or even billions of interacting particles in these areas [3, 4]. To address this, empirical problem computations will be applied, using a first-order nonlinear differential equation of the form

$$y'(x) = xy^2 + y^3 \qquad (1.1)$$

These equations are more complex than their linear counterparts, as they can exhibit a wide range of behaviors, such as multiple solutions, chaos and sensitivity to initial conditions [5]. Nonlinear differential equations are used to model various real-world phenomena, including population dynamics, fluid flow, electrical circuits and chemical reactions. Solving such equations often requires specialized numerical methods, as analytical solutions are typically difficult or impossible to obtain [6-8].

Numerical Analysts and Mathematicians have long been interested in the solutions to differential equations, as well as the physical phenomena they represent. Various numerical methods have been developed for solving first-order initial value problems of ordinary differential equations, with ongoing efforts to extend these methods to higher-order equations. Several notable studies in this area include works by [9-11], among many others. These methods often employ interpolation and collocation techniques to derive solutions of varying accuracy for first-order initial value problems. The study of ordinary differential equations, including their properties and solvability, remains a highly active field of research [12-14].

2.   Mathematical Formulation of the Method

This section showed the formulation of the method. The method is derived using the linear block approach [15].

The linear block approach is being of the form

$$y_{n+\xi} = \sum_{i=0}^{2} \frac{(\zeta h)^i}{i!} y_n^{(i)} + \sum_{i=0}^{4} \left(\varphi_{i\zeta} f_{n+i} \right), \quad \zeta = 0, \frac{1}{6}, \frac{1}{3}, \frac{1}{2}, \frac{2}{3}, \frac{5}{6}, 1 \tag{2.1}$$

is consider one after the others to obtain the method.
Differentiating of (2.1) once to obtain the block approach as

$$y_{n+\xi}^{(a)} = \sum_{i=0}^{1-a} \frac{(\zeta h)^i}{i!} y_n^{(i+a)} + \sum_{i=0}^{4} \sigma_{\zeta ia} f_{n+i}, \quad a = 1_{\left(0, \frac{1}{6}, \frac{1}{3}, \frac{1}{2}, \frac{2}{3}, \frac{5}{6}, 1\right)} \tag{2.2}$$

$\varphi_{\zeta i} = \Omega^{-1} M$ and $\sigma_{\zeta ia} = \Omega^{-1} N$ where

$$\Omega = \begin{pmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 0 & \frac{\left(\frac{1}{6}\right)^1}{1!} & \frac{\left(\frac{1}{3}\right)^1}{1!} & \frac{\left(\frac{1}{2}\right)^1}{1!} & \frac{\left(\frac{2}{3}\right)^1}{1!} & \frac{\left(\frac{5}{6}\right)^1}{1!} & \frac{(1)^1}{1!} \\ 0 & \frac{\left(\frac{1}{6}\right)^2}{2!} & \frac{\left(\frac{1}{3}\right)^2}{2!} & \frac{\left(\frac{1}{2}\right)^2}{2!} & \frac{\left(\frac{2}{3}\right)^2}{2!} & \frac{\left(\frac{5}{6}\right)^2}{2!} & \frac{(1)^2}{2!} \\ 0 & \frac{\left(\frac{1}{6}\right)^3}{3!} & \frac{\left(\frac{1}{3}\right)^3}{3!} & \frac{\left(\frac{1}{2}\right)^3}{3!} & \frac{\left(\frac{2}{3}\right)^3}{3!} & \frac{\left(\frac{5}{6}\right)^3}{3!} & \frac{(1)^3}{3!} \\ 0 & \frac{\left(\frac{1}{6}\right)^4}{4!} & \frac{\left(\frac{1}{3}\right)^4}{4!} & \frac{\left(\frac{1}{2}\right)^4}{4!} & \frac{\left(\frac{2}{3}\right)^4}{4!} & \frac{\left(\frac{5}{6}\right)^4}{4!} & \frac{(1)^4}{4!} \\ 0 & \frac{\left(\frac{1}{6}\right)^5}{5!} & \frac{\left(\frac{1}{3}\right)^5}{5!} & \frac{\left(\frac{1}{2}\right)^5}{5!} & \frac{\left(\frac{2}{3}\right)^5}{5!} & \frac{\left(\frac{5}{6}\right)^5}{5!} & \frac{(1)^5}{5!} \\ 0 & \frac{\left(\frac{1}{6}\right)^6}{6!} & \frac{\left(\frac{1}{3}\right)^6}{6!} & \frac{\left(\frac{1}{2}\right)^6}{6!} & \frac{\left(\frac{2}{3}\right)^6}{6!} & \frac{\left(\frac{5}{6}\right)^6}{6!} & \frac{(1)^6}{6!} \end{pmatrix}, \quad M = \begin{pmatrix} \frac{(\xi h)^1}{1!} \\ \frac{(\xi h)^2}{2!} \\ \frac{(\xi h)^3}{3!} \\ \frac{(\xi h)^4}{4!} \\ \frac{(\xi h)^5}{5!} \\ \frac{(\xi h)^6}{6!} \\ \frac{(\xi h)^7}{7!} \end{pmatrix}, \quad N = \begin{pmatrix} \frac{(\xi h)^{1-a}}{(1-a)!} \\ \frac{(\xi h)^{1-a}}{(1-a)!} \\ \frac{(\xi h)^{1-a}}{(1-a)!} \\ \frac{(\xi h)^{6-1}}{(1-a)!} \\ \frac{(\xi h)^{1-a}}{(1-a)!} \\ \frac{(\xi h)^{1-a}}{(1-a)!} \\ \frac{(\xi h)^{1-a}}{(1-a)!} \end{pmatrix} \tag{2.3}$$

Equation (2.1) and (2.2) are solved step by step through

$$\vartheta_\zeta, \quad \zeta = 0, \frac{1}{6}, \frac{1}{3}, \frac{1}{2}, \frac{2}{3}, \frac{5}{6}, 1.$$

The polynomial $x = x_s + th$, is being used in (2.3) to yield the continuous scheme of the form

$$q(x_s th) = \alpha_1 y_{s+1} + h \left(\beta_0 f_s + \beta_{\frac{1}{6}} f_{s+\frac{1}{6}} + \beta_{\frac{1}{3}} f_{s+\frac{1}{3}} + \beta_{\frac{1}{2}} f_{s+\frac{1}{2}} + \beta_{\frac{2}{3}} f_{s+\frac{2}{3}} + \beta_{\frac{5}{6}} f_{s+\frac{5}{6}} + \beta_1 f_{s+1} \right) \tag{2.4}$$

Where
$$\alpha_1 = 1$$

$$\beta_0 = -\frac{(t-1)^2\begin{pmatrix}7a+7b+7d-12t+7e+21t^2e+28t^3e+140t^4e+21at^2+28at^3+140at^4+21bt^2+28bt^3+140vt^4\\+21dt^2+28dt^3+140dt^4-7ae-7be-7de+14te-7ab-7ad-7bd+14at+14bt+14dt-18t^2\\-24t^3-30t^4-120t^5-21at^2e-168at^3e-21bt^2e-168bt^3e-21dt^2e-168dt^3e-21abt^2-168abt^3\\-21adt^2-168adt^3-21bdt^2-168bdt^3-14ate-14bte-14dte-14abt-14adt-14bdt+210abt^ee\\+210adt^2e210bdt^2e+210abdt^2+70abde-280abdte-6\end{pmatrix}}{420abde}$$

$$\beta_a = \frac{(t-1)^2\begin{pmatrix}-7b-7d+12t-7e-21t^2e-28t^3e-140t^4e-21bt^2-28bt^3-140bt^4-21dt^2-28bt^3-140dt^4\\+7dt^2+7de-14te+7bd-14bt-14bt+18t^2+24t^3+30t^4+120t^5+21bt^2e+168bt^3e+21dt^2e\\+168dt^3e+21bt^2+168bdt^3+21bdt^2+168bdt^3+14bte+14dte-14bdt-210abt^ee-6\end{pmatrix}}{420a(2a-1)(a-1)(a-e)(a-d)(a-b)}$$

$$\beta_b = -\frac{(t-1)^2\begin{pmatrix}-7a-7b+12t-7e-21t^2e-28t^3e-140t^4e-21at^2-28at^3-140at^4-21dt^2-28dt^3-140dt^4\\+7dt^4+7ae+7de+7ad-14te-14at-14dt+18t^2+24t^3+30t^4+120t^5+21at^2e+168at^3e+21dt^2e\\+168dt^3e+21adt^2+168adt^3+14ate+14dte+14dte+14adte-210abt^ee+6\end{pmatrix}}{420b(2b-1)(b-1)(b-e)(b-d)(a-b)}$$

$$\beta_{\frac{1}{2}} = -\frac{16(t-1)^2\begin{pmatrix}14a+14b+14d+20t+14e+42t^2e+56t^3e+70t^4e+42at^2+56at^3+70at^4+42bt^2+56bt^3+70bt^4\\+42dt^256dt^3+70dt^4-21ae-21be-21de+28te-21ab-21ad-21bd+28at+28bt+28dt-30t^2\\-40t^3-50t^4-60t^5-63at^3e-84at^3e-63bt^2e-84bt^3e-63dt^2e-84dt^3e-63abt^2-84abt^3-63adt^2\\-84adt^3-63bdt^2-84bdt^3+35abe+35ade+35bde-42ate-42bte-42dte+35abd-42abt-42adt\\-42bdt+105abt^ee+105adt^2e+105bdt^2e+105abdt^2-70abde+70abte+70adte+70bdte+70abdt\\-140abdte-10\end{pmatrix}}{105(2e-1)(2d-1)(2b-1)(2b-1)(2a-1)}$$

$$\beta_d = -\frac{(t-1)^2\begin{pmatrix}-7a-7b+12t-7e-21t^2e-28t^3e-140t^4e-21at^2-28at^3-140at^4-21bt^2-28bt^3-140bt^4\\+7ae+7be+7ab-14te-14at-14bt+18t^2+24t^3+30t^4+120t^5+21at^2e+168at^3e+21bt^2e\\+168bt^3e+21abt^2+168abt^3+14ate+14bte+14bte+14abt-210abet^2+6\end{pmatrix}}{420d(2d-1)(d-1)(d-e)(b-d)(a-d)}$$

$$\beta_e = -\frac{(t-1)^2\begin{pmatrix}7a+7b+7d-12t+21at^2+28at^3+140at^4+21bt^2+28bt^3+140bt^4+21dt^2+28dt^3+140dt^4\\-7ab-7ad-7bd+14at-7bt-7dt-18t^2-24t^3-30t^4-120t^5-21abt^2-168at^3e-21bt^2e\\-168abt^3-21adt^2-168adt^3-21bdt^2-168bdt^3-14abt-14adt-14bdt+210abdt^2-6\end{pmatrix}}{420\begin{pmatrix}-e^4+3e^5-2e^6+ae^3-3ae^4+2ae^5+be^3-3be^4+2be^5+de^3+3de^4+2de^5-abe^2+3abe^3\\-2abe^4+ade^2+3ade^3-2ade^4-bde^2+3bde^3-2bde^4+abde-3abde^2+2abde^3\end{pmatrix}}$$

$$\beta_1 = -\frac{(t-1)\begin{pmatrix}56a+56b+56d-56t+56e+56t^2e+56t^3e+56t^4e++56t^5e++56at^2+56at^3+56at^4+56bt^2\\140at^5+56bt^3+56bt^4+140bt^5+56dt^2+56dt^3+56dt^4+140dt^5-63ae-63be-63de+56te\\-63ab-63ad-63bd+56at+56bt+56dt-50t^2-50t^3-50t^4-50t^5-120t^6-63att^2e\\-63at^3e-160att^4e-63bt^2e-63bt^3e-168bt^4e-63dt^2e-63dt^3e-168dt^4e-63abt^2-63abt^3\\168abt^4-63adt^2-63adt^3-168adt^4-63bdt^2-63bdt^3-168bdt^4+70abe+70ade+70bde\\-63ate-63bte-63dte+70abd-63abt-63adt-63bdt+70abt^2e+210abt^3e+70bdt^2e+\\210bdt^3e+70abdt^2+210abdt^3-70abde+70abte+70adte-280abdt^2e-70abdte-50\end{pmatrix}}{420((-e+1)(d-1)(a-1))}$$

To get the unknown values of (2.3), we simplify $\sigma_{\zeta ia} = \Omega^{-1}N$ to obtain

$$y_{n+a} = y_n + h\left(\sigma_{115} f_n + \sigma_{120} f_{n+a} + \sigma_{125} f_{n+b} + \sigma_{130} f_{n+\frac{1}{2}} + \sigma_{135} f_{n+d} + \sigma_{140} f_{n+e} + \sigma_{145} f_{n+1} \right)$$

$$y_{n+b} = y_n + h\left(\sigma_{215} f_n + \sigma_{220} f_{n+a} + \sigma_{225} f_{n+b} + \sigma_{230} f_{n+\frac{1}{2}} + \sigma_{235} f_{n+d} + \sigma_{240} f_{n+e} + \sigma_{245} f_{n+1} \right)$$

$$y_{n+\frac{1}{2}} = y_n + h\left(\sigma_{315} f_n + \sigma_{320} f_{n+a} + \sigma_{325} f_{n+b} + \sigma_{330} f_{n+\frac{1}{2}} + \sigma_{335} f_{n+d} + \sigma_{340} f_{n+e} + \sigma_{345} f_{n+1} \right)$$

$$y_{n+d} = y_n + h\left(\sigma_{415} f_n + \sigma_{420} f_{n+a} + \sigma_{425} f_{n+b} + \sigma_{430} f_{n+\frac{1}{2}} + \sigma_{435} f_{n+d} + \sigma_{440} f_{n+e} + \sigma_{445} f_{n+1} \right)$$

$$y_{n+e} = y_n + h\left(\sigma_{515} f_n + \sigma_{520} f_{n+a} + \sigma_{525} f_{n+b} + \sigma_{530} f_{n+\frac{1}{2}} + \sigma_{535} f_{n+d} + \sigma_{540} f_{n+e} + \sigma_{545} f_{n+1} \right)$$

$$y_{n+1} = y_n + h\left(\sigma_{615} f_n + \sigma_{620} f_{n+a} + \sigma_{625} f_{n+b} + \sigma_{630} f_{n+\frac{1}{2}} + \sigma_{635} f_{n+d} + \sigma_{640} f_{n+e} + \sigma_{645} f_{n+1} \right)$$

(2.5)

Where

$$\begin{pmatrix} \sigma_{115} \\ \sigma_{120} \\ \sigma_{125} \\ \sigma_{130} \\ \sigma_{135} \\ \sigma_{140} \\ \sigma_{145} \end{pmatrix} = \begin{pmatrix} \frac{19089}{362880} \\ \frac{2713}{15120} \\ -\frac{15487}{120960} \\ \frac{293}{2835} \\ -\frac{6737}{120960} \\ \frac{263}{15120} \\ -\frac{863}{362880} \end{pmatrix}, \begin{pmatrix} \sigma_{215} \\ \sigma_{220} \\ \sigma_{225} \\ \sigma_{230} \\ \sigma_{235} \\ \sigma_{240} \\ \sigma_{245} \end{pmatrix} = \begin{pmatrix} \frac{1139}{22680} \\ \frac{47}{189} \\ \frac{11}{7560} \\ \frac{166}{2835} \\ -\frac{269}{7560} \\ \frac{11}{945} \\ -\frac{37}{22680} \end{pmatrix}, \begin{pmatrix} \sigma_{315} \\ \sigma_{320} \\ \sigma_{325} \\ \sigma_{330} \\ \sigma_{335} \\ \sigma_{340} \\ \sigma_{135} \end{pmatrix} = \begin{pmatrix} \frac{137}{2688} \\ \frac{27}{112} \\ \frac{387}{4480} \\ \frac{17}{105} \\ -\frac{243}{4480} \\ \frac{9}{560} \\ -\frac{29}{13440} \end{pmatrix}, \begin{pmatrix} \sigma_{415} \\ \sigma_{420} \\ \sigma_{425} \\ \sigma_{430} \\ \sigma_{435} \\ \sigma_{440} \\ \sigma_{445} \end{pmatrix} = \begin{pmatrix} \frac{143}{2835} \\ \frac{232}{945} \\ \frac{64}{945} \\ \frac{752}{2835} \\ \frac{29}{945} \\ \frac{8}{945} \\ \frac{4}{2835} \end{pmatrix}, \begin{pmatrix} \sigma_{515} \\ \sigma_{5120} \\ \sigma_{525} \\ \sigma_{530} \\ \sigma_{535} \\ \sigma_{540} \\ \sigma_{545} \end{pmatrix} = \begin{pmatrix} \frac{3715}{72576} \\ \frac{727}{3024} \\ \frac{2125}{24192} \\ \frac{125}{567} \\ \frac{3875}{24192} \\ \frac{235}{3024} \\ -\frac{275}{72576} \end{pmatrix}, \begin{pmatrix} \sigma_{615} \\ \sigma_{620} \\ \sigma_{625} \\ \sigma_{630} \\ \sigma_{635} \\ \sigma_{640} \\ \sigma_{645} \end{pmatrix} = \begin{pmatrix} \frac{41}{840} \\ \frac{9}{35} \\ \frac{9}{280} \\ \frac{34}{105} \\ \frac{9}{280} \\ \frac{9}{35} \\ \frac{41}{840} \end{pmatrix}$$

3   Basic Properties of the Block Method

3.1   Order and Error Constant

This subsection establishes the linear operator $\ell[y(x_i);h]$ associated with the newly derived method (2.5).

Proposition 1

The local truncation error of the newly derived scheme is $C_{07} h^{07} y^{07}(x_n) + 0(h^{08})$.

Proof

The linear difference operators associated with the hybrid method (2.5) are given by [5].

$$\ell[y(x_n);h] = y(x_n + ah) - \left(\alpha_1(x_\eta + h) + h\sum_{j=0}^{k}\left(\beta_j(x)f_{n+j} + \beta_k(x)f_{n+k}\right)\right), k = 0, a, b, \frac{1}{2}, d, e, 1$$

$$\ell[y(x_n);h] = y(x_n + bh) - \left(\alpha_1(x_\eta + h) + h\sum_{j=0}^{k}\left(\beta_j(x)f_{n+j} + \beta_k(x)f_{n+k}\right)\right), k = 0, a, b, \frac{1}{2}, d, e, 1$$

$$\ell[y(x_n);h] = y\left(x_n + \frac{1}{2}h\right) - \left(\alpha_1(x_\eta + h) + h\sum_{j=0}^{k}\left(\beta_j(x)f_{n+j} + \beta_k(x)f_{n+k}\right)\right), k = 0, a, b, \frac{1}{2}, d, e, 1 \qquad (3.1)$$

$$\ell[y(x_n);h] = y(x_n + dh) - \left(\alpha_1(x_\eta + h) + h\sum_{j=0}^{k}\left(\beta_j(x)f_{n+j} + \beta_k(x)f_{n+k}\right)\right), k = 0, a, b, \frac{1}{2}, d, e, 1$$

$$\ell[y(x_n);h] = y(x_n + eh) - \left(\alpha_1(x_\eta + h) + h\sum_{j=0}^{k}\left(\beta_j(x)f_{n+j} + \beta_k(x)f_{n+k}\right)\right), k = 0, a, b, \frac{1}{2}, d, e, 1$$

$$\ell[y(x_n);h] = y(x_n + h) - \left(\alpha_1(x_\eta + h) + h\sum_{j=0}^{k}\left(\beta_j(x)f_{n+j} + \beta_k(x)f_{n+k}\right)\right), k = 0, a, b, \frac{1}{2}, d, e, 1$$

If $y(x)$ is sufficiently differentiable, we can use the Taylor series to expand equation (3.1) in the power of h. It is critical to emphasize that the first non-zero term in each formula in Equation (3.1) is $C_{07}h^{07}y^{07}(x_n) + 0(h^{08})$

Definition 1. [5]

A linear multistep method is of order p if it satisfies the condition

$$c_0 = c_1 = c_2 = c_3 = \cdots = c_p = c_{p+1} = 0, c_{p+2} \neq 0, \text{ where}$$

$$c_0 = \sum_{j=0}^{k}\alpha_j$$

$$c_1 = \sum_{j=0}^{k}\left(j\alpha_j - \beta_j\right)$$

$$\vdots \qquad (3.2)$$

$$c_p = \sum_{j=0}^{k}\left[\frac{1}{p!}j^p\alpha_j - \frac{1}{(p-1)!}\left(j^{p-1}\beta_j\right)\right], p = 2, 3, \cdots, q+1$$

The parameter $c_{p+2} \neq 0$ is referred to as the error constant with the local truncation error defined as

$$x_{n+k} = c_{p+2}h^{p+2}y^{(p+2)}(x_n) + c_{p+3}h^{p+3}y^{(p+3)}(x_n) + c_{p+4}h^{p+4}y^{(p+4)}(x_n) + 0(h^{p+5}) \qquad (3.3)$$

$$\begin{bmatrix}
\sum_{j=0}^{\infty}\dfrac{(a)^j}{j!} - y_n - \sum_{j=0}^{\infty}\dfrac{h^{j+1}}{j!}y_n^{j+1}\left[\sigma_{120}(a)+\sigma_{125}(b)+\sigma_{130}\left(\dfrac{1}{2}\right)+\sigma_{135}(d)+\sigma_{140}(e)+\sigma_{145}(1)\right] \\[2mm]
\sum_{j=0}^{\infty}\dfrac{(b)^j}{j!} - y_n - \sum_{j=0}^{\infty}\dfrac{h^{j+1}}{j!}y_n^{j+1}\left[\sigma_{220}(a)+\sigma_{225}(b)+\sigma_{230}\left(\dfrac{1}{2}\right)+\sigma_{235}(d)+\sigma_{240}(e)+\sigma_{245}(1)\right] \\[2mm]
\sum_{j=0}^{\infty}\dfrac{\left(\frac{1}{2}\right)^j}{j!} - y_n - \sum_{j=0}^{\infty}\dfrac{h^{j+1}}{j!}y_n^{j+1}\left[\sigma_{320}(a)+\sigma_{325}(b)+\sigma_{330}\left(\dfrac{1}{2}\right)+\sigma_{335}(d)+\sigma_{340}(e)+\sigma_{345}(1)\right] \\[2mm]
\sum_{j=0}^{\infty}\dfrac{(d)^j}{j!} - y_n - \sum_{j=0}^{\infty}\dfrac{h^{j+1}}{j!}y_n^{j+1}\left[\sigma_{420}(a)+\sigma_{425}(b)+\sigma_{430}\left(\dfrac{1}{2}\right)+\sigma_{435}(d)+\sigma_{440}(e)+\sigma_{445}(1)\right] \\[2mm]
\sum_{j=0}^{\infty}\dfrac{(e)^j}{j!} - y_n - \sum_{j=0}^{\infty}\dfrac{h^{j+1}}{j!}y_n^{j+1}\left[\sigma_{520}(a)+\sigma_{525}(b)+\sigma_{530}\left(\dfrac{1}{2}\right)+\sigma_{535}(d)+\sigma_{540}(e)+\sigma_{545}(1)\right] \\[2mm]
\sum_{j=0}^{\infty}\dfrac{(1)^j}{j!} - y_n - \sum_{j=0}^{\infty}\dfrac{h^{j+1}}{j!}y_n^{j+1}\left[\sigma_{620}(a)+\sigma_{625}(b)+\sigma_{630}\left(\dfrac{1}{2}\right)+\sigma_{635}(d)+\sigma_{640}(e)+\sigma_{645}(1)\right]
\end{bmatrix} \tag{3.4}$$

Corollary 1 [5].

The newly derived method (2.5) has a local truncation error given by

$$\begin{aligned}
\left(6.7679\times10^{-09}\right)C_{07}h^{07}y^{07}(x_n)+0\left(h^{08}\right) \\
\left(5.0402\times10^{-09}\right)C_{07}h^{07}y^{07}(x_n)+0\left(h^{08}\right) \\
\left(5.9803\times10^{-09}\right)C_{07}h^{07}y^{07}(x_n)+0\left(h^{08}\right) \\
\left(5.0402\times10^{-09}\right)C_{07}h^{07}y^{07}(x_n)+0\left(h^{08}\right) \\
\left(6.7679\times10^{-09}\right)C_{07}h^{07}y^{07}(x_n)+0\left(h^{08}\right) \\
\left(5.9803\times10^{-09}\right)C_{07}h^{07}y^{07}(x_n)+0\left(h^{08}\right)
\end{aligned} \tag{3.5}$$

Therefore, the newly derived scheme is of uniform order seven as well as error constant is given by

$$C_8 = \begin{pmatrix}
6.7679\times10^{-09} \\
5.0402\times10^{-09} \\
5.9803\times10^{-09} \\
5.0402\times10^{-09} \\
6.7679\times10^{-09} \\
5.9803\times10^{-09}
\end{pmatrix}$$

3.2 Consistent

Traditionally, the method is consistent because the order of the method is order greater than or equal to one.

3.3 Zero stable

Definition 2. [5]

A linear multistep method is said to be zero stable as $h \to 0$ if the roots of the polynomial $\pi(r)=0$ satisfy $\left|\left[\sum A^0 R^{k-1}\right]\right| \le 1$, and those roots with $R=1$ must be simple.

Hence according to [5] it's found as

$$\pi(r) = \left| r \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} - \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \right| = \left| \begin{bmatrix} r & 0 & 0 & 0 & 0 & -1 \\ 0 & r & 0 & 0 & 0 & -1 \\ 0 & 0 & r & 0 & 0 & -1 \\ 0 & 0 & 0 & r & 0 & -1 \\ 0 & 0 & 0 & 0 & r & -1 \\ 0 & 0 & 0 & 0 & 0 & r-1 \end{bmatrix} \right| = r^6(r-1) \tag{3.6}$$

Then, solving for r in $r^6(r-1)$,

gives $r = 0, 0, 0, 0, 0, 1$. Therefore, the method is zero stable.

Dahlquist's theorem states that the scheme is convergent, and consistency and zero-stability are analyzed and fulfilled [5].

3.4. Convergence
Theorem 1. [5]
Consistency and zero-stability are both required and sufficient conditions for a linear multistep method to be convergent. Therefore, the newly derived scheme is convergent since it is consistent and zero-stable.

3.5. Linear Stability

Definition 3. [5]

The region of absolute stability of a numerical method is the set of complex values λh for which all solutions of the test problem $y' = -\lambda y$ will remain bounded as $n \to \infty$.

The concept of A-stability according to [5] is discussed by applying the test equation $y^{(k)} = \lambda^{(k)} y$

To yield
$$Y_m = \mu(z)Y_{m-1}, \ z = \lambda h \tag{3.7}$$

Where $\mu(z)$ is the amplification matrix of the form

$$\mu(z) = \left(\xi^0 - z\eta^{(0)} - z^1\eta^{(0)} \right)^{-1} \left(\xi^1 - z\eta^{(1)} - z^1\eta^{(1)} \right) \tag{3.8}$$

The matrix $\mu(z)$ has Eigen values $(0, 0, \cdots, \xi_k)$ where ξ_k is called the stability function.

Thus, the stability function of the method is given by

$$\zeta = -\frac{\left(\begin{array}{l} 367275240z^6 - 10000752628z^5 + 79785191834z^4 + 506079675630z^3 \\ + 18277711257925z^2 - 4328380929600z + 4444263936000 \end{array} \right)}{\left(\begin{array}{l} 870912000z^6 + -12802406400z^5 + 106077081600z^4 - 576108288000z^3 \\ + 2057529600000z^2 - 4444263936000z + 4444263936000 \end{array} \right)} \tag{3.9}$$

The boundary locus method is used to generate the hybrid method's stability polynomial. The polynomial is defined as

$$\left. \begin{array}{l} \bar{h}(w) = \left(-\frac{1}{326592}w^5 + \frac{1}{326592}w^6 \right)h^6 + \left(-\frac{7}{77760}w^5 - \frac{7}{77760}w^6 \right)h^5 + \left(-\frac{29}{19440}w^5 + \frac{29}{19440}w^6 \right)h^4 \\ + \left(-\frac{7}{432}w^5 - \frac{7}{432}w^6 \right)h^3 + \left(-\frac{25}{216}w^5 + \frac{25}{216}w^6 \right)h^2 + \left(-\frac{1}{2}w^5 + \frac{1}{2}w^6 \right)h - w^5 + w^6 \end{array} \right\} \tag{3.10}$$

The polynomial is used to plot the region as
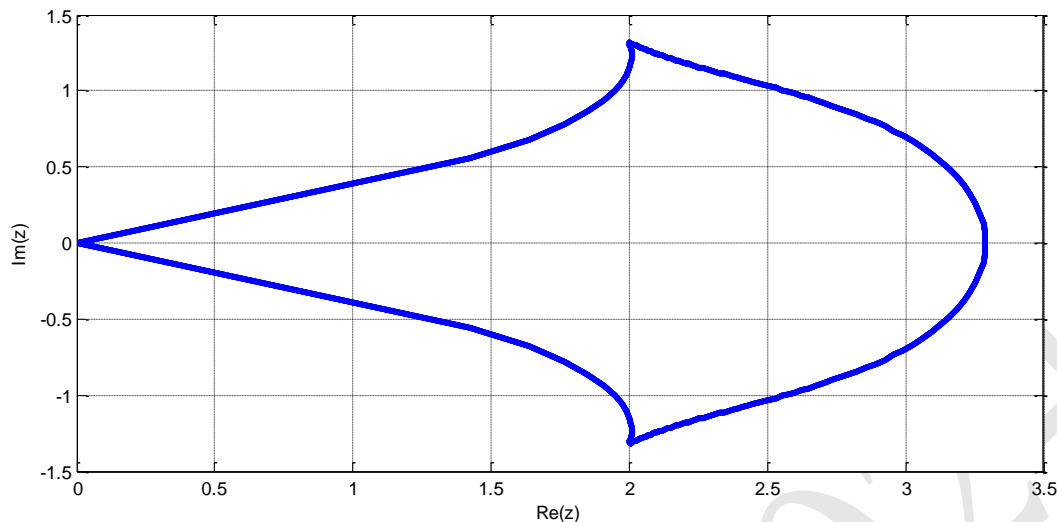
Fig. 1: Showing an *A-stable* region of absolute stability of the new Method

4.2 Numerical Experiments

The newly derived block hybrid method (2.5) shall be applied on four nonlinear first order initial value problems ordinary differential equations of the form (1.1) as presented below.

The results obtained on the application of nonlinear first order initial value problems ordinary differential equations were compared with the existing methods of [16-21].

Problem 4.1

Consider a nonlinear first order initial value problems ordinary differential problem which was solved by [16, 17] formulated as follows:

$$y'(x) = -10(y-1)^2, \; y(0) = 2, \; h = 0.01 \tag{4.1}$$

with the exact solution given by

$$y(x) = 1 + \frac{1}{1+10x} \tag{4.2}$$

Problem 4.2

Given a nonlinear first order ordinary differential problem which was addressed by [17, 18] formulated as follows:

$$y' = \frac{1}{2}(1-y), \; y(0) = \frac{1}{2}, \tag{4.3}$$

Which has the exact solution as

$$y(x) = 1 - \frac{1}{2}e^{-\frac{1}{2}x} \tag{4.4}$$

Problem 4.3

Given a nonlinear first order ordinary differential problem which was addressed by [19, 20] formulated as follows:

$$y' = -y^2, \; y(0) = 1, \; 0 \le x \le 1 \tag{4.5}$$

Whose exact solution is given as

$$y(x) = \frac{1}{1+x} \tag{4.6}$$

Problem 4.4:

Given a nonlinear first order ordinary differential problem which was addressed by [21] formulated as follows:

$$y' = 4 - 4y + y^2 = 0, \; y(0) = 1, \; 0 \le x \le 1 \tag{4.7}$$

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Whose exact solution are

$$y(x) = \frac{2x-1}{x-1}$$
(4.8)

Table 4.2: The results of application problem 4.2 with [16, 17].

x	Exact Solution	Computed Solution	ENM	E[16]	E[17]
0.1	1.9090909090909090909	1.9090909090909082926910	7.98218e-14	1.75330e-10	1.55825e-06
0.2	1.8333333333333333333	1.8333333333333323389440	9.94389e-14	2.32000e-10	2.39975e-06
0.3	1.7692307692307692308	1.8333333333333323389440	9.88733e-14	2.41150e-10	2.83045e-06
0.4	1.7142857142857142857	1.7142857142857142244730	9.18384e-14	2.31400e-10	3.02094e-06
0.5	1.6666666666666666667	1.6666666666666658342770	8.32390e-14	2.14840e-10	3.06956e-06
0.6	1.6250000000000000000	1.6249999999999992517240	7.48276e-14	1.96600e-10	3.03457e-06
0.7	1.5882352941176470588	1.5882352941757987960	6.71792e-14	1.78870e-10	2.95115e-06
0.8	1.5555555555555555556	1.5555555555549513440	6.04212e-14	1.62500e-10	2.84088e-06
0.9	1.5263157894736842105	1.5263157894736298969500	5.45155e-14	1.47730e-10	2.71713e-06
1.0	1.5000000000000000000	1.4999999999999995062980	4.93702e-14	1.34570e-10	2.58816e-06

Table 4.2: The results of application problem 4.2 with [17, 18]

x	Exact Solution	Computed Solution	ENM	E[18]	E[17]
0.1	0.52438528774964299546	0.52438528774964299546	0.00000e-00	3.01260e-17	1.99840e-15
0.2	0.54758129098202021342	0.54758129098202021342	0.00000e00	5.49357e-17	3.88578e-15
0.3	0.56964601178747109638	0.56964601178747109639	1.00000e-20	5.83702e-17	5.44009e-15
0.4	0.59063462346100907066	0.59063462346100907067	1.00000e-20	5.89498e-17	6.99441e-15
0.5	0.61059960846429756588	0.61059960846429756590	2.00000e-20	4.20996e-17	8.21565e-15
0.6	0.62959088965914106696	0.62959088965914106699	3.00000e-20	8.43851e-17	9.54792e-15
0.7	0.64765595514064328282	0.64765595514064328285	3.00000e-20	8.85311e-17	1.05471e-14
0.8	0.66483997698218034963	0.66483997698218034965	2.00000e-20	9.33604e-17	1.13243e-14
0.9	0.68118592418911335343	0.68118592418911335346	3.00000e-20	2.67745e-17	1.22125e-14
1.0	0.69673467014368328820	0.69673467014368328823	3.00000e-20	2.98500e-16	1.28786e-14

Table 4.3: The results of application problem 4.3 with [19, 20]

x	Exact Solution	Computed Solution	ENM	E[19]	E[20]
0.01	0.99009900990099009899	0.99009900990099009901	2.00000e-20	2:40000e-04	2.91799e-11
0.02	0.98039215686274509804	0.98039215686274509800	4.00000e-20	5.60000e-04	3.71577e-11
0.03	0.97087378640776699029	0.97087378640776699023	6.00000e-20	7.10000e-04	3.93663e-11
0.04	0.96153846153846153846	0.96153846153846153839	7.00000e-20	8.40000e-04	3.39936e-11
0.05	0.95238095238095238095	0.95238095238095238086	9.00000e-20	9.40000e-04	2.94922e-11
0.06	0.94339622641509433962	0.95238095238095238086	1.10000e-19	1.10000e-04	2.61278e-11
0.07	0.93457943925233644860	0.94339622641509433951	1.30000e-19	1.10000e-03	2.31487e-11
0.08	0.92592592592592592593	0.93457943925233644847	1.40000e-19	1.30000e-03	6.80704e-11
0.09	0.91743119266055045872	0.92592592592592592579	1.60000e-19	1.50000e-03	8.31745e-11
0.10	0.90909090909090909091	0.90909090909090909074	1.70000e-19	1.60000e-02	7.50649e-11

Table 4.4: The results of application problem 4.4 with [21].

x	Exact Solution	Computed Solution	ENM	E[21]
0.1	0.98989898989898989899	0.98989898989898989897	2.00000e-20	1.11400e-04
0.2	0.97959183673469387755	0.97959183673469387751	4.00000e-20	1.85700e-03
0.3	0.96907216494845360825	0.96907216494845360819	6.00000e-20	2.53600e-04
0.4	0.95833333333333333333	0.95833333333333333326	7.00000e-20	7.14800e-05
0.5	0.94736842105263157895	0.94736842105263157885	1.00000e-19	9.72000e-06
0.6	0.93617021276595744681	0.93617021276595744670	1.10000e-19	2.06400e-06
0.7	0.92473118279569892473	0.92473118279569892460	1.30000e-19	2.80400e-07
0.8	0.91304347826086956522	0.91304347826086956507	1.50000e-19	5.29200e-08
0.9	0.90109890109890109890	0.90109890109890109873	1.70000e-19	7.16300e-09
1.0	0.88888888888888888889	0.88888888888888888889	0.00000e00	1.09300e-09

4.3   Discussion of Results and Conclusion

In the analysis of Problems 4.1 and 4.2, the new method shows a significant improvement in accuracy over existing methods, such as those proposed by [16-18]. The computed solutions produced by the new method align closely with the exact solutions, demonstrating its precision in solving nonlinear first-order initial value problems. This accuracy is reflected in the consistently smaller absolute errors compared to the larger errors of the other methods, making the new approach a more reliable tool for precise approximations. The method's ability to maintain a minimal error margin throughout various independent variables further underscores its robustness and effectiveness in solving differential equations.

The examination of Problem 4.3 highlights the remarkable accuracy of the new method, particularly in comparison to the approaches of [19, 20]. The new method's computed solutions align closely with the exact solutions, consistently producing minimal absolute errors. In contrast, the methods by [19, 20] show larger error margins, indicating less precise approximations. The ability of the new method to maintain accuracy across the entire range of values underscores its stability and robustness. Similarly, in Problem 4.4, the new method demonstrates a clear advantage over the method proposed by [21], with its computed solutions closely matching the exact solutions and maintaining lower error margins. This precision and consistency further validate the new method as a reliable tool for solving nonlinear first-order ordinary differential equations with high accuracy.

In conclusion, the study introduces an implicit one-step block hybrid method for solving nonlinear first-order ordinary differential equations (ODEs). By employing the linear block approach, the new method enhances accuracy, stability and computational efficiency, addressing common challenges such as error propagation in nonlinear problems. The method consistently demonstrated superior performance in Problems 4.1 to 4.4, surpassing existing approaches by [16-21], with smaller absolute errors and a close alignment to exact solutions. The stability analysis further validated its robustness, making this method a highly reliable and effective tool for solving nonlinear first-order ODEs.

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PAPER BATTERY: A NOVEL APPROACH FOR AN ULTRA THIN, FLEXIBLE AND ENVIRONMENTALLY FRIENDLY ENERGY SOLUTION FOR COMMUNICATION DEVICES IN NIGERIA

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Abstract

This paper presents the process of producing an environmentally friendly battery using waste paper management. The physical and chemical parameters of the paper were determined. Conductive Carbon Nano Tubes and a combination of some powdered metals were made into a paste together with the waste paper. The waste paper served as insulator and also was used for stacking to boost the voltage output. Preliminary result showed the waste paper to have a P^H value of 5.6-6.7, mean moisture of 8.3% and density of $0.054g/m^2$ (wet basis). Analysis of tensile strength indicated the strength derived from factors like fiber strength, length and fiber bonding of the waste paper, which provided the information on the quality of the paper in terms of web breaking. The result of the battery showed potential and could be an alternative source of energy in the near future. The paper battery is found to have the advantage of portability, foldability, light weight and potentiality to charging within a short time while discharging at as low phase. The process was found to be a low-cost method of producing though it has other shortcomings.

Keyword: *Paper battery, Nanotube, Waste paper, Communication devices*

1.Introduction

Paper batteries are composed of paper (cellulose) and a Carbon nanotube (CNT). Cellulose is a complex organic substance found in pulp. It is not digestible by humans when consumed. A Carbon Nanotubes (CNT) is a very tiny cylinder formed from a single sheet of carbon. These carbon atoms are rolled to form cylinder. Their conductivity is better than best semiconductor and strength is more than steel, [1]. A paper battery is very flexible, very thin and light in weight, due to this property; it can be manufactured in any desired shape and size. It can be used as a super capacitor, high-energy battery and as a self-rechargeable [1].

In other words, it is a flexible, ultra-thin energy storage and production device formed by combining carbon nanotubes with a conventional sheet of cellulose-based paper [2]. Paper battery has intrinsic porous structure, which is not only act as separator with low impendence than commercial separator, but it can also be recycled. This separator also functions as the mechanical support for battery making it more flexible, cheaper and easier to manufacture. Paper battery contains carbon nanotubes, each about one millionth of a centimeter thick, which act as an electrode [2]. The nanotubes are embedded in a sheet of paper soaked in ionic liquid electrolytes, which conduct the electricity. A stack of such papers makes a paper battery. While a conventional battery contains a number of separate components, the paper battery integrates all of the battery components in a single structure, making it more energy efficient. Recent researches suggest that carbon nanotubes could eventually offer the simplest hope of implementing the versatile battery, which might shrink our gadgets more.

Along with its ability to function in temperatures up to 300 degrees Fahrenheit and down to 100 below zero, the device can be completely integrated and could be printed like paper [3] paper battery acts both as charge producing device (battery) and charge storing device (capacitor) [4]. Having Nano scale structure, it is environmentally friendly and has the potential to be integrated into a wide range of today's digital and electronic devices, such as mobile phones, portable camera, notebook computers etc. Because of its composition and structural features, the paper battery is not harmful and it is fully recyclable.

2 Methodology

2.1 Materials and Methods

The method involved the use of silicon as substrate and the Nanotube grows on the substrate. Waste paper, in this case is used instead of cellulose for the filling of gaps in the matrix, which also combine with the Nanotubes. Next the matrix is allowed to dry and cooled through refrigeration at 150o C. The amalgamated Nanotubes and the paper are stripped off. With these two sheets, CNT Ink is applied to serve as the electrode.

2.2 Some of the material and tools used:

Nano rods
Surface adhesives agent
Ionic salt solution
Oven of Temp. 150oC
Voltmeters
Ammeters
Ohmmeters
Cardboards
PPEs
Zinc salt (ZnSO4)
Magnesium salt (MgSO4)
Iron rods
Papers
Conductivity meter
Thermometer
Brushes

2.3 Physical parameters of Paper Used for Paper Battery

Waste paper samples were collected as stated in previous report from offices within School of Technology, Kano State Polytechnic and was used for the analysis of the physical and chemical properties.

2.4 Temperature Determination

Procedure: The Temperature of the paper sample before and after biodegradation was taken and recorded using (LCD H-9283 multi-Stem thermometer model). A quantity of 10g of paper sample was soaked into 100ml of sterile distilled water, and allowed to stand for a few minutes, A thermometer was inserted into the solution of the paper, readings was taken and recorded (APHA, 2001).

2.5 PH – Value Determination

PH of paper sample was determined before and after biodegradation analysis using a Jenway (PHep model). 10g of paper was carefully weighed and placed into 250cm beaker, 100ml of distilled water was added to the beaker, the suspension was stirred several times with a clean glass rod and allowed to stand for 30 minutes, the PH meter prove was inserted into the solution of the paper, the readings were taken and recorded. (APHA, 2001). The PH value obtained for the waste paper analyzed was in the range of 5.6-6.7

2.6 Moisture Content.

Moisture content was measured on a wet basis and determined by dividing the oven dry mass by the initial (wet) mass according to the equation:

Moisture content MC, %=Initial Mass−Oven dry mass/Initial mass ∗100%
Moisture content is an important variable that influence voltage measurement. The higher the moisture content the less the expected voltage increase. For the waste paper analyzed, a mean value of 8.3% was obtained.

2.7 Density

The density of waste paper or bulk is an important parameter in relation to the quality of the paper. The term is also used to express volume of thickness of a paper in relation to weight. It reciprocates density.

The properties of smoothness, opaqueness, darkness and gloss all increase with increase in density. The density of the waste paper sample measured was found to be a mean 1of 0.54 g/m2. The standard weight or gram mage for a new paper is 60-90 g/m2

2.8 Tensile strength

The tensile strength of a paper is the maximum stress to break a strip of paper sheet. It is also defined as the ability of a material to resist deformation by subjecting it to pure tension.

Tensile strength is a fundamental property of a material. The mean result of tensile strength, brightness and opacity of the waste paper is 4.16, 75.22 and 78.44 respectively.

2.9 Chemical parameters of Paper Used for Paper Battery

Shredded waste paper samples collected were rinsed with distilled water to remove particulate matter and then dried at room temperature and packaged in a clean polyethene bag for the analysis. 100g of the paper sample were soaked in water in a clean 1000ml beaker container for 1hr. All chemicals used in the analysis of waste paper were of Analytical grade. Stock solutions of 1000mg/L Ni, Cu, Cd, Pb and Fe were prepared from their salts in deionized distilled H_2O and made up to 1000ml.

Serial dilutions were made from 1000mg/L for the determination of the heavy metals was carried out using Atomic Absorption Spectroscopy (AAS). The concentration some elements like sodium (Na), potassium (K), calcium (Ca), and magnesium (Mg) were also determined using flame photometer. The result of the metal analysis is shown below:

The heavy metal content of the recycled waste paper was evaluated and found to contain the highest concentration of Copper (21.0 mg kg-1).

Their main sources are the printing colorants used in printing process. Presence of copper in high concentration/quantity and also being a good conductor helps in the conductance of the paper battery making process. Nickel, zinc, lead and cadmium have concentrations of 19.4mg kg-1, 2.8mg kg-1, 1.8mg kg-1 and 0.089mg kg respectively in decreasing order of quantity.

Cadmium was found to contain the least concentration in the sample waste paper. Presence of heavy metals in waste paper is generally associated with the chemical additives used in the paper making process

H/Metals	M.C(%)	O.C(%)	Pb	Cu(mg/kg1)	Fe(mg/kg1)	Mn(mg/kg1)	Zn(mg/kg1)	Ni(mg/kg1)	Cd(mg/kg1)
Conc.	2.24	56.26	1.88	21.0	3.4	2.1	2.8	19.4	0.089

Table:2 Result of some alkali/alkali earth metals analysis (mg kg^{-1}) of the waste paper used in paper battery

Alkali/earth metals	Na	K	Ca	Mg
Conc. (mg/kg^1)	0.50	0.089	19.4	21.0

2.10 Preparation of Carbon Nanotube (CNT)

From the name, Carbon Nanotubes (CNT) are made from/of Carbon with diameters measured in nanometers. They could be referred to as Single Walled Carbon nanotube (SWCNT) and are allotropes of carbon, intermediate between fullerene cages and flat grapheme. It could also be termed as Multi Walled Carbon nanotube (MWCNT) consisted of nested single-wall carbon nanotube bound by van dear Waals interaction a tree like structure. CNTs are known to exhibit remarkable electrical conductivity, high tensile strength and thermal conductivity.

Single Walled Carbon Nanotube was prepared using arc discharge method. The method uses high temperature, normally above 1700oC for CNT synthesis. The electric arc generated between the graphite results in the production of an extremely high temperature that is sufficient to sublimate the carbon.
This results in the formation of CNT with fewer structural defects.

Fig. 1. Compacted shredded paper

2.11 Testing of Paper Battery

Various compositions of the Carbon nanotube, waste paper and electrolyte were made and tested for voltage. The different compositions of the carbon nanotube that serves as cathode and the various anodes made from Magnesium, Silver and Calcium salts.

The various readings observed in voltage is shown below:

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Fig. 2. Testing the paper battery

Fig 3. Testing the paper battery

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Fig 7: CNT applied onto the paper

Fig 4. Applying the paste on the paper

Fig 8: Charging the paper battery

Fig 5. Charging the battery

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An Agent-Based Model of Deformed Wing Virus A and B Co-Infection

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Abstract. The Deformed Wing Virus (DWV) is a major threat to honeybee populations, causing colony collapse disorder and threatening global agriculture and biodiversity. DWV-A and DWV-B, co-infect honeybees, leading to severe outcomes. An agent-based model simulates the interactions between bees, mites, and viruses, incorporating factors like viral transmission rate, pathogenicity, and immune response. The model predicts that the presence of both DWV strains leads to synergistic interactions, resulting in heightened virulence and accelerated colony decline. Furthermore, the findings suggest that targeted interventions, such as mite control and selective breeding for disease-resistant bees, can mitigate the adverse effects of co-infection. This study provides a novel computational framework to explore the multifaceted interactions between DWV strains and their hosts, offering valuable insights into the mechanisms driving colony health and disease resilience. The agent-based approach facilitates the examination of various hypothetical scenarios and intervention strategies, contributing to effective management practices to safeguard honeybee populations. By enhancing our understanding of DWV co-infection dynamics, this research aims to inform policymakers and guide practical efforts to combat the ongoing challenges facing honeybee health, ultimately supporting the sustainability of pollinator-dependent ecosystems and agricultural productivity.

Keywords: Deformed wing virus, Colony collapse disorder, Co-infection, Strains.

1   Introduction

The honeybee, crucial for modern agriculture, provides essential services like pollination, medicine, and nutrition [1]. However, the global decline in honeybee colonies, driven by parasites, threatens agricultural security. The survival of individual bees depends on the colony's population, and varroa mite invasion increases infection prevalence [2,3].

Deformed wing virus (DWV) is a common honeybee virus that causes wing deformities in adult honeybees and affects all life stages [4]. It spreads globally and can be contracted through various routes, including food consumption by workers to varroa mites. Four DWV variants have been reported, with DWV-B being more widespread in Europe and DWV-A in North America. DWV-B has similar or lower virulence in honeybee pupae, but understanding pupal mortality before adulthood is complex [5,6].

The DWV-A and DWV-B variants initially have higher viral loads, but 72 hours after coinfection, DWV-B replicates to higher levels [7]. Superinfection exclusion occurs at the colony level, and DWV-B competes with DWV-A [8]. Varroa mites have developed resistance to synthetic acaricides, making biological control methods effective. Research suggests that African honeybees may be less threatened

by pests and diseases due to their resistance, highlighting the importance of understanding resistance mechanisms [9]. Mathematical models have been utilized to study honeybee virus transmission dynamics within and between hives [10,11]. Britton and White's first model used weighted directed graphs, revealing overt infection could occur without mites [12]. Paxton's model analyzed DWV-A and DWV-B variants, emphasizing the relationship between variants [13].

Agent-based modeling (ABM) is a simulation approach to model systems comprising interacting agents. It consists of agents that interact within an environment. Progress suggests that ABM could have far-reaching effects on how researchers use models as electronic laboratories to identify promising research directions [14,18].

Several computational models have been proposed to examine honeybee issues, including the BEEPOP model, which predicts colony growth by considering factors like egg laying, brood development, worker aging, and foraging days [15]. The VARROAPOP model considers the impact of Varroa mite parasitism on colony dynamics, focusing on worker longevity reduction [16]. The BEEHAVE model, developed by Becher et al. (2014), incorporates Varroa mites, viruses, landscape changes, and pesticide exposure on colony growth and survival. It generates cohorts of individuals aged from egg to adult, identifying critical factors for overwintering success, including weather conditions and fall supplemental feeding. The model also simulates the sublethal effects of pesticides, including impaired forager orientation, floral handling time, brood care, and increased forager mortality [17].

In this study, we proposed an agent-based model that will aid in exploring, quantitatively, the mode of spread of DWV variants A and B. In order to intervene in virus transmission, the model includes intervention techniques such as mite resistance breeding, hive cleaning, and miticide use.

2   Methodology
2.1   Modeling the environment

We use Agent-Based Modeling, where the interactions of an autonomous agent (in this case, Varroa mites) with a spatially explicitly modeled environment can be formalized using defined memory and decision heuristics, to validate adaptive hypotheses in disease transmission and parasite infestation (Chittka, 2006). Specifically, we used NetLogo (Wilensky, 1999), a simple programmable agent-based modeling system for simulating natural and social phenomena, to model the environment of Varroa mites and the bee agents. We modeled the interaction that developed over time between the agents and environmental changes, such as illuminant variations.
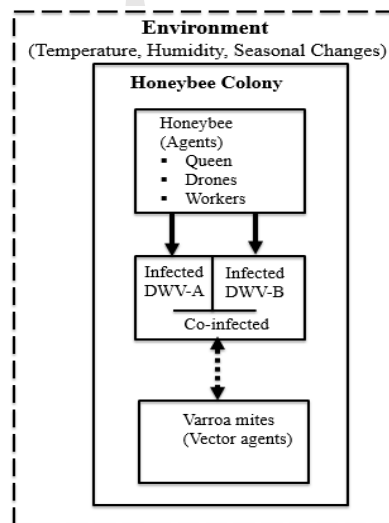
Fig. 1. The schematic diagram describes the interaction between honeybees, Varroa mites, and their environment.

In case of the environment, external factors such as temperature and humidity could affect the transmission rates of DWV. Also, interventions by the beekeepers, for example, treatments or good hive management practices, can affect the transmission dynamics of the DWV-A. Within the colony, the role of primary agents members of the colony (workers, drones, queen) can facilitate or delay the transmission. Furthermore, the transition between various states (healthy, infected, coinfected, dead) plays a role in the dynamics of the members. Varroa Mites act as vectors for DWV, transmitting the virus from infected bees to healthy bees. *Note that, dashed arrows indicate interactions, while solid arrows show transitions.*

2.2 Modeling the Colony

The model considers interaction between susceptible honeybees and infected mites and virus-free mites and infected honeybees. The model considers the following assumptions as follows:

1. As in [10] we assume that effective egg survival into adults results from broodcare through division of labor.
2. In accordance with [3] we presume that neither of the illness variations has affected the queen bee. This presumption is thought to be essential in order for us to presume that the queen's rate of egg production is unaffected by viruses or mites.
3. The assumption that the rate of mite parasitism is proportionate to the amount of mite-honeybee encounters accounts for the severity of mite infestation.
4. There is a strong correlation between the mite's lifespan and the honeybee's lifespan. Our model incorporates this by considering the population of honeybees, including both adult and brood bees, as a function of carrying capacity.
5. The two stages of female mite life phoretic and reproductive within brood cells are taken into account in the model formulation.
6. In consistent with [10] we presume that both adult and brood bees orally consume the virus pathogens.

The set up of the model depicted in Fig. 2 is designed to investigate the impact of the transmission dynamics of the two variants and the possibility of their co-infection in the presence of some control strategies. The model considers three (3) populations, viz., brood bees, B; adult bees, H; and mites (P-parasitic mites and R-reproductive mites). The brood bees are set to acquire infection following parasitism by infected reproductive mites, while the adult bees acquire infection from parasitic mites. Both brood and adult bees could acquire a second infection despite being infected with one variant (DWV-A or DWV-B). Literature has shown that, mites are the transmitters of the variants of DWV and thus, we allow the mites to acquire either of the variants. However, we assume that a mite carry only one infection at a time. To simulate the model, we set up an uncontaminated hive with 25,000 brood bees (out of which 5000 are drone broods, 20,000 are walker drones) 20,000 healthy adult honeybees, 10 virus-free carrying mites. We then introduced 5 infected honeybees and 1 virus-carrying mite. The virus was set to occur as the infected mite parasite on the healthy bee. We assume that throughout the simulation time, the queen bee will not be infected by either of the virus variants. The assumption is integrated to allow us assume that the queen bee's egg-laying rate will not be affected by either the mites or the virus.
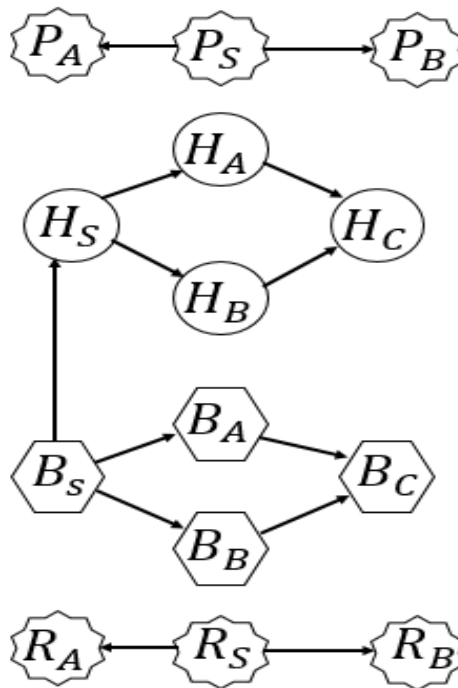
Fig. 2: The flow diagram describing the interaction between honey bees and mites.

The indeces *A, B* and *C* denote variants A, B and coinfection, respectively. The compartments *H, B, P* and *R* denote adult bees, brood bees, parasitic mite and reproductive mites, respectively. The arrows show progression from one class to the other.

2.3 NetLogo

NetLogo is a programmable modeling environment designed for social and natural phenomena simulation. Since its inception in 1999 by Uri Wilensky, the Center for Connected Learning and Computer-Based Modeling has been actively updating it (Wilensky, 1999–2019). NetLogo has been an excellent tool for beginners because of its simplicity. Thousands or even hundreds of thousands of autonomous "agents" can be programmed by modelers. This allows for the investigation of the relationship between an individual's microbehavior and the macro-level patterns resulting from their interaction. However, it has some challenges or limitations, such as performance, scalability, and flexibility. These limitations may make it less suitable for large-scale, complex, or highly detailed simulations. The next multiagent modeling language in the StarLogo and StarLogoT family is NetLogo. The screenshot is portrayed in Fig. 3.
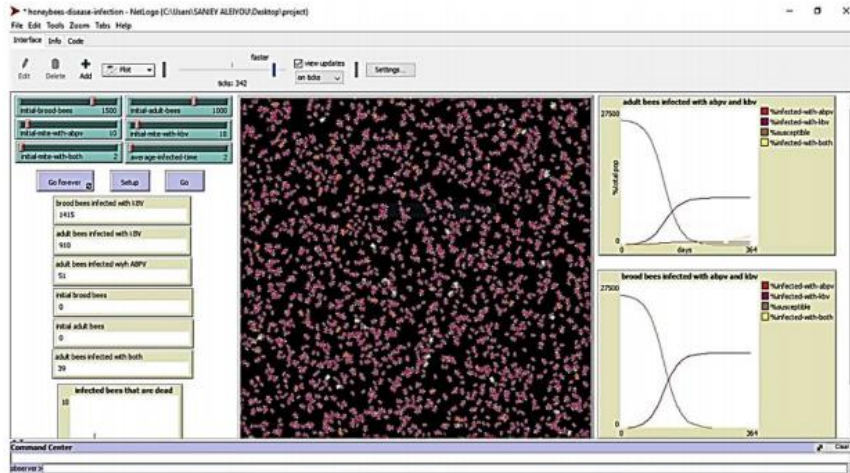
Fig. 3: NetLogo simulation environment

3   Result and Discussion

In this section, we simulated the model described in Figure 1 using an agent based model software, NetLogo 6.0.2. We experimented with a colony set as in Section 2.2. Deep learning techniques are used to train the model designed and with the help of Machine learning algorithms, we make some forecast. The accuracy of the analysis results was assessed via a combination of both linear and nonlinear algorithms. The dataset used in the analysis is generated from Netlogo software.

The dataset is split into 10 groups, and we used 9 groups for training and 1 for testing. Validation is performed ten times through a random selection of groups for training and testing. Average Classification Accuracy (ACA) is calculated. The result of the 10-Fold Cross Validations is presented in Table:

Table 1: Classifier performance of 10-Fold Cross Validations on the dataset

Categories	10-Fold Cross Validation						
	Accuracy Rate (%) for Classification Methods						
	ACA	LR	LDA	KNN	CART	NB	SVM
DWV-A infected bees	0.6782	0.4712	0.6851	0.6978	0.8892	0.7767	0.5762
DWV-B infected bees	0.2522	0.2622	0.2966	0.4401	0.5763	0.4132	0.2322
Co- infected with DWV-A and DWV-B	0.4251	0.5321	0.5475	0.7677	0.8723	0.7675	0.4201

Using MATLAB, the dataset generated from the simulation environment is used for the following plot.
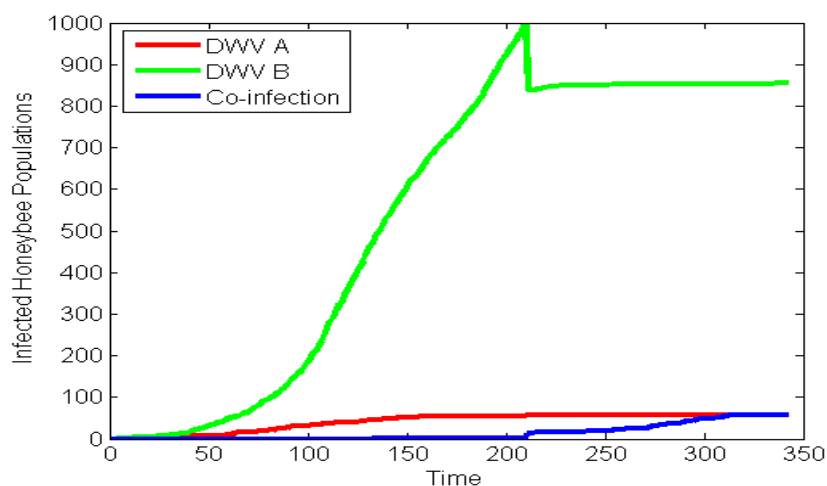
Fig. 4: Graph of estimated cases of DWV-A, B and co-infections.

It is evident from the graph Fig. 4 that, DWV-A cases maintain a steady but slow increase, indicating that this strain of the virus spreads more slowly through the population. In the case of DWV B, a rapid increase in the infected population is realized, suggesting a much higher transmission rate or a more aggressive infection dynamic. The plateau observed around the 200 days might indicate a temporary saturation point, followed by another increase due to new susceptible individuals or environmental changes. Cases of co-infection follow a steady increase similar to DWV A but at a slightly faster rate. This suggests that co-infection might have a compounded effect, but it is not as aggressive as DWV B alone.

This result implies that,, a rapid increase in the cases of DWV-B infections is of major concern for honeybee populations. This is because it can lead to a high number of infected bees within the shortest possible time. Consequently, this will have a serious effect on colony health and survival. DWV-A and co-infection have a less dramatic effect but still show a significant increase in populations, which can contribute to colony decline over a long time compared to DWV-B.

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TOPOLOGY AND TOPOLOGICAL SPACE IN FINITE GEOMETRY WITH VARIABLES IN Z$_d$

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Abstract
In this paper, partial ordered relation is researched, finite geometry and its subgeometries are explored. An investigation of topology which exists in near-linear and non-near-linear finite geometry G$_d$ is delved into. The outcome of this work shows an existence of the concept of topology and topological space on non-near-linear finite geometry with variables in Z$_d$. The complexity shown in this work demonstrated the existence of relationship between a geometry as a structure and its subgeometries as its substructures.
Keywords: Topology, ring of integers modulo d, lines, finite geometry.

1. INTRODUCTION
Let Z^+ represents a set of positive integers. Z_d, the ring of integers modulo d, where $d \in Z^+$. For quite some time, finite quantum systems with variables in Z_d had received enormous attention with a special focus on mutually unbiased bases. Likewise in recent times, the weak mutually unbiased bases are getting more interest from researchers [1-2]. This might be because such concepts have a significant role in quantum computation and information. For instance, [3] discussed an existence of lattice structure between lines in near-linear finite geometries and its sublines. This paper establishes a relationship between topological space and the concept of non-near-linear finite geometry with variables in Z_d. The lines of this non-near-linear finite geometry are taken both through the origin $(0,0)$ and through shifted arbitrary origin (a,b) [2-3].

Previous studies focused on near-linear finite geometry. In this type of geometry, two lines have at most one point of intersection. An extension to this phenomenon is called non-near-linear geometry. It is a situation where two lines intersect at more than one point [4].

In this work, each element of the set $\{D(d)\}$ represents a finite geometry. The notation $\{D(d)\}$ represents the set of proper divisors of d. Any pairs of set of divisors form a topology in this work.

The breakdown of this work is as follows; concepts used in this work are defined in section 2, titled, preambles. Section 3 focuses on near-linear geometry. In section 4, non-near-linear finite geometry and its subgeometry is discussed. Topology and topological spaces in non-near-linear finite geometry are showcased in section 5. In section 6, the result of the findings is demonstrated using examples. The conclusion of this work is given in section 7.

2. PREAMBLES
   i.   The ring of integers modulo d is denoted by Z_d where $d \in Z^+$, and Z^+ represents set of positive integers. In this work, $G_d = Z_d^2$. So we use them interchangeably.
   ii. $|Z^*|$ is $\phi(d)$ where Z^* represents the set of invertible element in Z_d and $\phi(d)$ is referred to as Euler Phi function. It is defined as
$$\phi(d) = \prod_{j=1}^{\ell}(p_j - 1) \tag{1}$$
   iii. $\psi(d)$ is called Dedekind psi function where;
$$\psi(d) = \prod_{j=1}^{\ell}(p_j + 1), \ p_j = prime \tag{2}$$
   Here in this work, d is expressed as products of power of an integer.

3. NEAR-LINEAR FINITE GEOMETRY
In general concept, a space $S(P, L)$ is a system of points P and line L such that every line L is a subset of P and certain axioms are satisfied.
A near linear space is an incident structure $I(P, L)$ of points P and lines L such that;
   i.   Any line has at-least two points.
   ii.   Two lines meet in at most one point.

In this work, a near-linear space is defined as follows:

$$G_d = (L_d, P_d)$$

Where, P_d represents points on the line L_d.

L_d denotes lines with point P_d, where

$$L_d = \{\alpha a, \alpha b | a, b \epsilon Z_d, \alpha \epsilon Z_d\} \qquad (1)$$

Lemma: Two distinct lines of a near-linear finite geometry meet in at-most one point.

Proof:

Let $G_d = Z_d^2$

$Z_d^2 = Z_d \times Z_d$ represents lines with points in G_d. For d a prime, intersection of any pair of arbitrary lines yields a point. Hence confirm the lemma.

4. NON-NEAR-LINEAR GEOMETRY AND ITS SUB-GEOMETRY WITH VARIABLES IN Z_d

This subsection discusses the concept of finite geometry. Here two lines in a phase-space Z_d^2 meet in at least one point. Equation (1) discusses a line through the origin (0,0). This concept was discussed in 2. Shifted origin is introduced and investigated in this work. In it a line through an arbitrary point ϑ, s is named as a shifted origin. It is defined as follows:

$$L_d = \{\alpha a + \vartheta, \alpha b + s | a, b, \vartheta, s \epsilon Z_d, \}, \alpha \epsilon Z_d \qquad (2)$$

$\alpha \epsilon Z_d$ is a cyclic module over a ring of integer modulo d.

Mathematically, it is defined as the pair (P_d, L_d) in $G_d = Z_d^2$. Here,

P_d represents points in a line and L_d represents lines in G_d where,

$$P_d = \{(e, f) | e, f \in Z_d\} \qquad (3)$$

From some results obtained, we confirm the following propositions.

1. If $b \in Z_d^*$ then $L(\alpha, \beta) = L(b\alpha, b\beta)$

    Now, Z_d^* represents the set of invertible elements in Z_d

    Also, if $b \in Z_d - Z_d^*$ then $L(\alpha, \beta) \, mod(d) \subset L(b\alpha, b\beta) \qquad (4)$

    Hence $L(b\alpha, b\beta) \prec L(\alpha, \beta)$, where $\prec$ represents partial ordering.

    We confirm that $L(\alpha, \beta)$ is a maximal line in G_d if $GCD(\alpha, \beta) \in Z_d^*$ and $L(\alpha, \beta)$ is a subline in G_d if $GCD(\alpha, \beta) \in Z_d - Z_d^*$

2. Suppose we define a line in the finite geometry G_d as in the equation (3)

    Now $L(\alpha, \beta)$ can also be;

    $$L(s\alpha, s\beta) = \{(s\xi\alpha, s\xi\beta) | \xi \in Z_d\} \xi \in Z_{\xi d} \qquad (5)$$

    at the same time the line $L(\xi\alpha, \xi\beta)$ in $G_{\xi d}$ is a subline of

    $$L(\alpha, \beta) = \{(s'\alpha, s'\beta) | s' = 0, \ldots, \xi d - 1\}$$

3. If two maximal lines have q points in common $q | d$.

    The q points give a subline $L(\alpha, \beta)$ where $\alpha, \beta \in \frac{d}{q} Z_q$.

If we consider the sub-geometry G_q, the subline $L(\alpha, \beta)$ in G_d is a maximal line in G_q. There is a $\psi(d)$ maximal line in sub-geometry G_q of finite geometry G_d.

The ring of integers Z_d and the Cartesian products, that is $Z_d \times Z_d$ is used extensively in this work to form finite geometry where all the lines are derived. The lines under this geometry form a non-near-linear finite geometry.

$$G_d = Z_d^2 = Z_d \times Z_d \qquad (6)$$

5. TOPOLOGY AND TOPOLOGICAL SPACE ON NON-NEAR-LINEAR FINITE GEOMETRY

A topological space is a set endowed with a structure called a topology, which allows defining continuous deformation of subspaces, and more generally, all kinds of continuity [5].

This section demonstrates how a phase-space finite geometry forms a topological space with its subsets as topology. This is discussed further thus:

Definitions V.I: A set X together with the family of its subset τ is a topological space if fulfils the following conditions:

    i.   The empty set and the whole set are elements of τ, that is, $\varphi, X \in \tau$

    ii.   The union of any finite member of τ is also an element of τ

    iii.   The intersection of any finite member of τ is also an element of τ

Definitions V.II: A set X together with the topology τ, that is (X, τ) is a topological space.

Hence in this work, a non-near-linear geometry with variables in Z_d where d is a non-prime integer is a phase-space that forms a topological space. The ring of integers modulo d is considered to be the set X, while the geometric combination $G_d = Z_d^2 = Z_d \times Z_d$ is taken as the topology. Thus, $(Z_d, Z_d \times Z_d)$ is a topological space. This phenomenon is shown to exist both when the geometric lines are taken through any arbitrary points in the geometry as defined in equations 3 and 4.

5. EXAMPLES

(a) Taking the geometry $G_{10} = Z_{10}^2$

In this example, we want to show how the finite geometric space $G_{10} = Z_{10}^2$ forms a topological space. We take the origin of the geometric lines from (0,0)

(a) Taking the geometry $G_{10} = Z_{10}^2$, lines of the geometry are shown thus

L(0,0) is distinct

L(0,1) ={(0,0)(0,1)(0,2)(0,3)(0,4)(0,5)(0,6)(0,7)(0,8)(0,9)}

L(0,2) ={(0,0)(0,2)(0,4)(0,6)(0,8)(0,0)(0,2)(0,4)(0,6)(0,8)}

L(0,5) is distinct

L(1,0) ={(0,0)(1,0)(2,0)(3,0)(4,0)(5,0)(6,0)(7,0)(8,0)(9,0)}

L(1,1)={(0,0)(1,1)(2,2)(3,3)(4,4)(5,5)(6,6)(7,7)(8,8)(9,9)}

L(1,2) ={(0,0)(1,2)(2,4)(3,6)(4,8)(5,0)(6,2)(7,4)(8,6)(9,8)}

L(1,3) ={(0,0)(1,3)(2,6)(3,9)(4,2)(5,5)(6,8)(7,1)(8,4)(9,7)}

L(1,4) ={(0,0)(1,4)(2,8)(3,2)(4,6)(5,0)(6,4)(7,8)(8,2)(9,6)}

L(1,5) ={(0,0)(1,5)(2,0)(3,5)(4,0)(5,5)(6,0)(7,5)(8,0)(9,5)}

L(1,6) ={(0,0)(1,6)(2,2)(3,8)(4,4)(5,0)(6,6)(7,2)(8,8)(9,4)}

L(1,7) ={(0,0)(1,7)(2,4)(3,1)(4,8)(5,5)(6,2)(7,9)(8,6)(9,3)}

L(1,8) ={(0,0)(1,8)(2,6)(3,4)(4,2)(5,0)(6,8)(7,6)(8,4)(9,2)}

L(1,9) ={(0,0)(1,9)(2,8)(3,7)(4,6)(5,5)(6,4)(7,3)(8,2)(9,1)}

L(2,0) ={(0,0)(2,0)(4,0)(6,0)(8,0)(0,0)(2,0)(4,0)(6,0)(8,0)}

L(2,1) ={(0,0)(2,1)(4,2)(6,3)(8,4)(0,5)(2,6)(4,7)(6,8)(8,9)}

L(2,2) ={(0,0)(2,2)(4,4)(6,6)(8,8)(0,0)(2,2)(4,4)(6,6)(8,8)}

L(2,3) ={(0,0)(2,3)(4,6)(6,9)(8,2)(0,5)(2,8)(4,1)(6,4)(8,7)}

L(2,4) ={(0,0)(2,4)(4,8)(6,2)(8,6)(0,0)(2,4)(4,8)(6,2)(8,6)}

L(2,5)= {(0,0)(2,5)(4,0)(6,5)(8,0)(0,5)(2,0)(4,5)(6,0)(8,5)}

L(2,6) ={(0,0)(2,6)(4,2)(6,8)(8,4)(0,0)(2,6)(4,2)(6,8)(8,4)}

L(2,7) ={(0,0)(2,7)(4,4)(6,1)(8,8)(0,5)(2,2)(4,9)(6,6)(8,3)}

L(2,8) ={(0,0)(2,8)(4,6)(6,4)(8,2)(0,0)(2,8)(4,6)(6,4)(8,2)}

L(2,9) ={(0,0)(2,9)(4,8)(6,7)(8,6)(0,5)(2,4)(4,3)(6,2)(8,1)}

L(5,0) is distinct

L(5,1) ={(0,0)(5,1)(0,2)(5,3)(0,4)(5,5)(0,6)(5,7)(0,8)(5,9)}

L(5,2) ={(0,0)(5,2)(0,4)(5,6)(0,8)(5,0)(0,2)(5,4)(0,6)(5,8)}

L(5,5) is distinct

The following results were generated from equation (2)

$$L(\alpha, \beta) = \{(s\alpha, s\beta) | \alpha, \beta \in Z_d\} s \in Z_d$$
$$L(0,1) \cong L(0,3) \cong L(0,7) \cong L(0,9)$$
$$L(1,0) \cong L(3,0) \cong L(7,0) \cong L(9,0)$$
$$L(1,1) \cong L(3,3) \cong L(7,7) \cong L(9,9)$$
$$L(1,2) \cong L(3,6) \cong L(7,4) \cong L(9,8)$$
$$L(1,3) \cong L(3,9) \cong L(7,1) \cong L(9,7)$$
$$L(1,4) \cong L(3,8) \cong L(7,2) \cong L(9,6)$$
$$L(1,5) \cong L(3,5) \cong L(7,5) \cong L(9,5)$$
$$L(1,6) \cong L(3,8) \cong L(7,2) \cong L(9,4)$$
$$L(1,7) \cong L(3,1) \cong L(7,9) \cong L(9,3)$$
$$L(1,8) \cong L(3,4) \cong L(7,6) \cong L(9,2)$$
$$L(1,9) \cong L(3,7) \cong L(7,3) \cong L(9,1)$$
$$L(2,1) \cong L(6,3) \cong L(4,7) \cong L(8,9)$$
$$L(2,3) \cong L(6,9) \cong L(4,1) \cong L(8,7)$$
$$L(2,5) \cong L(6,5) \cong L(4,5) \cong L(8,5)$$
$$L(2,7) \cong L(6,1) \cong L(4,9) \cong L(8,3)$$
$$L(0,2) \cong L(0,4) \cong L(0,6) \cong L(0,8)$$
$$L(2,0) \cong L(4,0) \cong L(6,0) \cong L(8,0)$$

$$L(2,2) \cong L(4,4) \cong L(6,6) \cong L(8,8)$$
$$L(2,4) \cong L(4,8) \cong L(6,2) \cong L(8,6)$$
$$L(2,6) \cong L(4,2) \cong L(6,8) \cong L(8,4)$$
$$L(2,8) \cong L(4,6) \cong L(6,4) \cong L(8,2)$$
$$L(0,5), \quad L(5,0), \quad L(5,5)$$

Checking for topological space using the axioms of topology and topological space

Axiom 1:

$\varphi, X \in \tau$, here $X = Z_{10}$, $\tau = Z_{10} \times Z_{10}$.

Clearly the empty set φ is an element of the topology. That is $\varphi = L(0,0) \in \tau = Z_{10} \times Z_{10}$

Again, the whole set X is an element of τ

Hence Axiom 1 is satisfied.

Axiom 2:

Finite union of subset of $Z_{10} \times Z_{10}$ is also an element of $Z_{10} \times Z_{10}$.

Clearly the union of any finite subset of $Z_{10} \times Z_{10}$ is a member element of $Z_{10} \times Z_{10}$. That is;

    i. $L(1,1) \cup L(2,5) \cup L(8,2) \in Z_{10} \times Z_{10}$

    ii. $L(3,4) \cup L(5,6) \in Z_{10} \times Z_{10}$

    iii. $L(0,5) \cup L(5,0) \cup L(5,5) = \{(0,0)(0,5)(5,0)(5,5)\} \in Z_{10} \times Z_{10}$

Hence Axiom 2 is satisfied.

Axiom 3

Finite intersection of elements of $Z_{10} \times Z_{10}$ is again an element of $Z_{10} \times Z_{10}$

Clearly the finite intersection of elements of $Z_{10} \times Z_{10}$ is an element of $Z_{10} \times Z_{10}$

    i. $L(1,1) \cap L(2,5) = (0,0) \in Z_{10} \times Z_{10}$

    ii. $L(3,4) \cap L(5,6) = \{(0,0), (5,0)\} \in Z_{10} \times Z_{10}$

Hence Axiom 3 is also satisfied.

Thus, we conclude that the geometric combination $Z_{10} \times Z_{10}$ is a topology, and the combination $(Z_{10}, Z_{10} \times Z_{10})$ forms a topological space.

(b) For a shifted origin say a line through point $(2,3)$, we check for topological space using the axioms of topology and topological space thus.

Axiom 1:

$\varphi, X \in \tau$, here $X = Z_{10}$, $\tau = Z_{10} \times Z_{10}$.

Clearly the empty set φ is an element of the topology. That is $\varphi = L(2,3) \in \tau = Z_{10} \times Z_{10}$

Again, the whole set X is an element of τ

Hence axiom 1 is satisfied.

Axiom 2

Finite union of subset of $Z_{10} \times Z_{10}$ is also an element of $Z_{10} \times Z_{10}$.

Clearly the union of any finite subset of $Z_{10} \times Z_{10}$ is a member element of $Z_{10} \times Z_{10}$. That is;

    i. $L(1,1) \cup L(2,5) \cup L(8,2) \in Z_{10} \times Z_{10}$

    ii. $L(3,4) \cup L(5,6) \in Z_{10} \times Z_{10}$

    iii. $L(0,5) \cup L(5,0) \cup L(5,5) = \{(2,3)(2,8)(7,3)(7,8)\} \in Z_{10} \times Z_{10}$

Hence axiom 2 is satisfied

Axiom 3

Finite intersection of elements of $Z_{10} \times Z_{10}$ is again an element of $Z_{10} \times Z_{10}$

Clearly the finite intersection of elements of $Z_{10} \times Z_{10}$ is an element of $Z_{10} \times Z_{10}$

    i. $L(1,1) \cap L(2,5) = (2,3) \in Z_{10} \times Z_{10}$

    ii. $L(3,4) \cap L(5,6) = \{(2,3), (7,3)\} \in Z_{10} \times Z_{10}$

Hence axiom 3 is satisfied.

Thus, we conclude that the geometric combination $Z_{10} \times Z_{10}$ is a topology, and the combination $(Z_{10}, Z_{10} \times Z_{10})$ forms a topological space, taking the shifted arbitrary origin.

7 CONCLUSION

Lines in finite geometry were studied. This paper focused on the relationships within subgeometries of a finite geometry. As an extension of our previous work in 18, lines in finite geometry were defined about arbitrary points. It was named a

shifted origin. Our findings confirmed an existence of topology by taking a set which in our work represents points in a finite geometry and collection of all its subgeometries as the subset.

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STOCHASTIC MODEL OF BOKO HARAM INSURGENCE WITH COUNTER TERRORIST OPERATIONS IN NORTH- EAST, NIGERIA

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ABSTRACT

The rise of Boko Haram activities in Northern Nigeria, particularly in the North-East, has led to frequent killings and the destruction of both public and private property, especially in areas like Yobe and Maiduguri. The safety of lives and property in this region is no longer guaranteed. In this study, we proposed and examined a stochastic model to understand and manage the dynamics of Boko Haram insurgency alongside counter-terrorism operations. We derived the differential equations that form the basis of the model and conducted simulations using the adaptivetau package in R. The findings indicate that counter-terrorism strategies have a significant effect on combating Boko Haram insurgencies. Consequently, we recommend that the Nigerian Army, with substantial support from the Air Force, intensify efforts to overcome the Boko Haram insurgency, including the acquisition of modern weaponry, the establishment of vigilante groups, and the implementation of rehabilitation programs to maintain the defeat of Boko Haram.

KEYWORDS: Stochastic, Boko- Haram, Counter- Terrorist

1 INTRODUCTION

Jama'atu Ahlis Sunna Lidda'awati wal-Jihad, commonly referred to as "Boko Haram," represents the most extreme form of violence in Nigeria's Fourth Republic. As of now, Nigeria is the third most affected country globally by terrorism, a ranking it has maintained since 2015. According to the 2020 Global Terrorism Index (GTI), only Iraq and Afghanistan have worse rankings than Nigeria, which has been grappling with violent insurgency in its northeastern region since 2009. While the majority of attacks occur in northern and North-East Nigeria, there have also been a considerable number of incidents in other areas. Notable attacks have taken place in Gombe, Kano,

Kaduna, Jos, and Bauchi States, as well as in the Federal capital, Abuja, with the potential for more incidents in the future. Targets have included public venues where large groups of people gather, such as places of worship, markets, shopping centers, hotels, bars, restaurants, football viewing areas, displacement camps, transportation hubs, government buildings, and educational institutions (including schools, colleges, and universities), as well as international organizations. These attacks have often occurred during religious and public holidays in crowded locations, as well as during election periods[4]. The frequency and intensity of terrorism have risen, yet, despite the growing violence, terrorists continue to function within self-imposed limits. While terrorism is a global issue, its impact is not uniform across different regions. There is no singular reason that accounts for why certain societies experience higher rates of terrorist violence than others. Additionally, terrorists tend to use a restricted set of techniques that have seen little evolution over time [2].

The significant levels of terrorism and violence in Nigeria, perpetrated by fundamentalist groups such as ISWAP-Boko Haram, militants, and bandits, have intensified concerns among both the local population and the international community. This situation has severely impacted the economy, and the violence has transcended mere religious or political issues. Numerous meetings, summits, and conferences have been organized in an effort to address this crisis, but none have proven effective. Additionally, despite the federal government investing millions of naira to restore security in the country, these efforts have not yielded the desired results [4].

The group's ability to carry out attacks has become increasingly advanced, with evidence suggesting that some members may have been trained in bomb-making and other terrorist methods by Al-Qaeda-linked organizations in the northern and

eastern regions of the continent. A series of assaults on churches between December 2011 and February 2012 indicates a deliberate strategy to provoke a widespread sectarian conflict aimed at destabilizing the country.

2 METHODOLOGY

We develop a stochastic model to analyze Boko Haram activities with counter-terrorism strategies. The behavior of Boko Haram was treated as a continuous-time birth-death stochastic process. This is represented by (X(t):t), where X(t) denotes the stochastic process, and the model is illustrated in the diagram below:
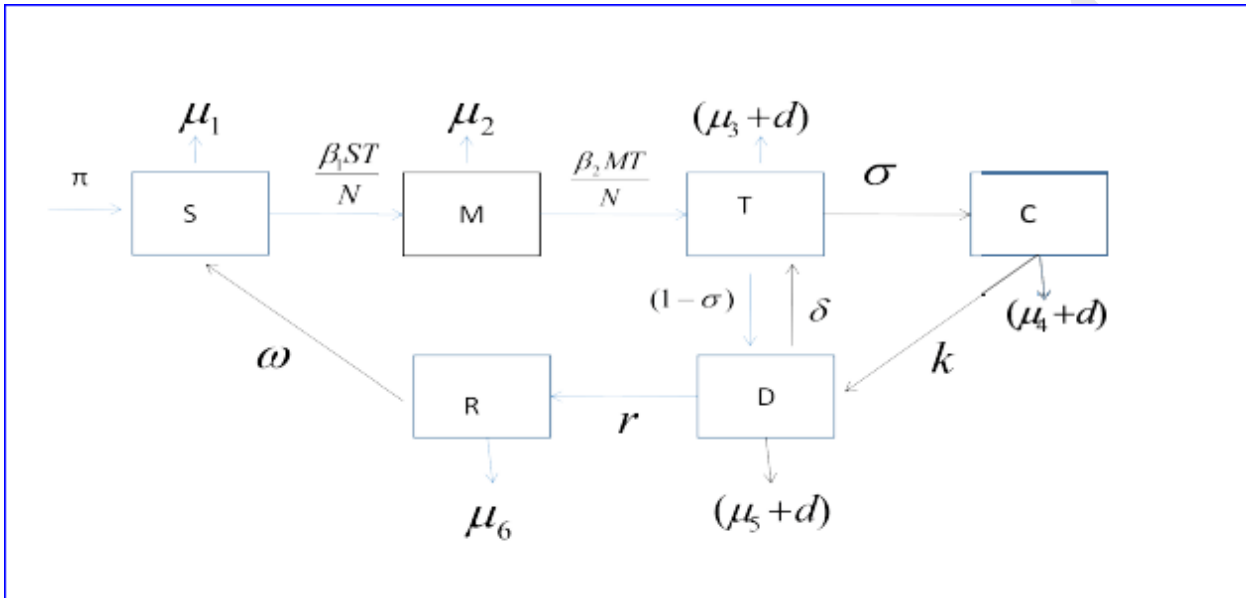
Figure 1: Model diagram

Based on the model presented above, we initially calculated the different transition probabilities by defining ($X1 = S$, $X2 = M$, $X3 = T$, $X4 = C$, $X5 = D$, $X6 = R$) as a collection of random variables that correspond to the states of Susceptible, Moderate, Terrorist, Combatant, Detention, and Repentance, respectively. The transition intensities and probabilities are summarized in the table below;

Table 1. Cumulative Transition Markov Chain

EVENT	VARIABLES	TRANSITIONS
$\pi\Delta(t) + o(\Delta t)$	$X_1+1, X_2, X_3, X_4, X_5, X_6$	1, 0, 0, 0, 0, 0
$m_{12}\Delta(t) + o(\Delta t)$	$X_1-1, X_2+1, X_3, X_4, X_5, X_6$	-1, +1, 0, 0, 0, 0
$m_{13}\Delta(t) + o(\Delta t)$	$X_1-1, X_2, X_3+1, X_4, X_5, X_6$	-1, 0, +1, 0, 0, 0
$m_{23}\Delta(t) + o(\Delta t)$	$X_1, X_2-1, X_3+1, X_4, X_5, X_6$	0, -1, +1, 0, 0, 0
$m_{34}\Delta(t) + o(\Delta t)$	$X_1, X_2, X_3-1, X_4+1, X_5, X_6$	0, 0, -1, +1, 0, 0
$m_{35}\Delta(t) + o(\Delta t)$	$X_1, X_2, X_3-1, X_4, X_5+1, X_6$	0, 0, -1, 0, +1, 0
$m_{36}\Delta(t) + o(\Delta t)$	$X_1, X_2, X_3-1, X_4, X_5, X_6+1$	0, 0, -1, 0, 0, +1
$m_{41}\Delta(t) + o(\Delta t)$	$X_1+1, X_2, X_3, X_4-1, X_5, X_6$	+1, 0, 0, -1, 0, 0
$m_{53}\Delta(t) + o(\Delta t)$	$X_1, X_2, X_3+1, X_4, X_5-1, X_6$	0, 0, +1, 0, -1, 0
$m_{56}\Delta(t) + o(\Delta t)$	$X_1, X_2, X_3, X_4, X_5-1, X_6+1$	0, 0, 0, 0, -1, +1

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$m_{65}\Delta(t) + o(\Delta t)$	$X_1, X_2, X_3, X_4, X_5{+}1, X_6{-}1$	0, 0, 0, 0, +1, -1
$\mu_1\Delta(t) + o(\Delta t)$	$X_1 - 1$	-1, 0, 0, 0, 0, 0
$\mu_2\Delta(t) + o(\Delta t)$	$X_2 - 1$	0, -1, 0, 0, 0, 0
$\mu_3\Delta(t) + o(\Delta t)$	$X_3 - 1$	0, 0, -1, 0, 0, 0
$\mu_4\Delta(t) + o(\Delta t)$	$X_4 - 1$	0 ,0 ,0 -1, 0, 0
$\mu_5\Delta(t) + o(\Delta t)$	$X_5 - 1$	0, 0, 0, 0, -1, 0
$\mu_6\Delta(t) + o(\Delta t)$	$X_6 - 1$	0, 0, 0, 0, 0, -1

The probabilities of an event occurring as a result of transitions are determined using a series of difference equations referred to as Kolmogorov equations. In the context of continuous-time birth-death stochastic processes, we have:;

$$p_{x_1, x_2, x_3, x_4, x_5, x_6}(t + \Delta t) = P\pi\Delta t\,\square p_{x_1+1}(t) + m_{12}(x_1 - 1)(x_2 + 1)\Delta t\,\square p_{x_1-1,x_2+1}(t)$$

$$+\mu_1(x_1 + 1)\Delta t\,\square p_{x_1-1,x_2+1}(t) + m_{13}(x_1 - 1)(x_3 + 1)\Delta t\,\square p_{x_1-1,x_3+1}(t) + \mu_1(x_1 + 1)\Delta t\,\square p_{x_1-1,x_3+1}(t)$$

$$+m_{23}(x_2 - 1)(x_3 + 1)\Delta t\,\square p_{x_2-1,x_3+1}(t) + \mu_2(x_2 + 1)\Delta t\,\square p_{x_2-1,x_3+1}(t)$$

$$+m_{34}(x_3 - 1)(x_4 + 1)\Delta t\,\square p_{x_3-1,x_4+1}(t) + \mu_3(x_3 + 1)\Delta t\,\square p_{x_3-1,x_4+1}(t)$$

$$+m_{35}(x_3 - 1)(x_5 + 1)\Delta t\,\square p_{x_3-1,x_5+1}(t) + \mu_3(x_3 + 1)\Delta t\,\square p_{x_3-1,x_5+1}(t)$$

$$+m_{36}(x_3 - 1)(x_6 + 1)\Delta t\,\square p_{x_3-1,x_6+1}(t) + \mu_3(x_3 + 1)\Delta t\,\square p_{x_3-1,x_6+1}(t)$$

$$+m_{41}(x_4 - 1)(x_1 + 1)\Delta t\,\square p_{x_4-1,x_1+1}(t) + \mu_4(x_4 + 1)\Delta t\,\square p_{x_4-1,x_1+1}(t)$$

$$+m_{53}(x_5 - 1)(x_3 + 1)\Delta t\,\square p_{x_5-1,x_3+1}(t) + \mu_5(x_5 + 1)\Delta t\,\square p_{x_5-1,x_3+1}(t)$$

$$+m_{56}(x_5 - 1)(x_6 + 1)\Delta t\,\square p_{x_5-1,x_6+1}(t) + \mu_5(x_5 + 1)\Delta t\,\square p_{x_5-1,x_6+1}(t)$$

$$+m_{63}(x_6 - 1)(x_3 + 1)\Delta t\,\square p_{x_6-1,x_3+1}(t) + \mu_6(x_6 + 1)\Delta t\,\square p_{x_6-1,x_3+1}(t)$$

$$+m_{65}(x_6 - 1)(x_5 + 1)\Delta t\,\square p_{x_6-1,x_5+1}(t) + \mu_6(x_6 + 1)\Delta t\,\square p_{x_6-1,x_5+1}(t)$$

$$-\begin{bmatrix} 1 + P\pi + (\mu_1 + m_{12} + m_{13})(x_1 + 1) + (\mu_2 + m_{23})(x_2 + 1) \\ +(\mu_3 + m_{34} + m_{35} + m_{36})(x_3 + 1) + (\mu_4 + m_{41})(x_4 + 1) \\ +(\mu_5 + m_{53} + m_{56})(x_5 + 1) + (\mu_6 + m_{63} + m_{65})(x_6 + 1) \end{bmatrix}\square p_{x_1, x_2, x_3, x_4, x_5, x_6}(t)$$

(1)

Differentiating equation (1) using first principle, this gives us our Kolmogorov Forward Differential Equation below:

$$\frac{dp_{x_1,x_2,x_3,x_4,x_5,x_6}(t)}{dt} = P\pi \cdot p_{x_1+1}(t) + m_{12}(x_1-1)(x_2+1)\cdot p_{x_1-1,x_2+1}(t)$$

$$+\mu_1(x_1+1)\cdot p_{x_1-1,x_2+1}(t) + m_{13}(x_1-1)(x_3+1)\cdot p_{x_1-1,x_3+1}(t) + \mu_1(x_1+1)\cdot p_{x_1-1,x_3+1}(t)$$

$$+m_{23}(x_2-1)(x_3+1)\cdot p_{x_2-1,x_3+1}(t) + \mu_2(x_2+1)\cdot p_{x_2-1,x_3+1}(t)$$

$$+m_{34}(x_3-1)(x_4+1)\cdot p_{x_3-1,x_4+1}(t) + \mu_3(x_3+1)\cdot p_{x_3-1,x_4+1}(t)$$

$$+m_{35}(x_3-1)(x_5+1)\cdot p_{x_3-1,x_5+1}(t) + \mu_3(x_3+1)\cdot p_{x_3-1,x_5+1}(t)$$

$$+m_{36}(x_3-1)(x_6+1)\cdot p_{x_3-1,x_6+1}(t) + \mu_3(x_3+1)\cdot p_{x_3-1,x_6+1}(t)$$

$$+m_{41}(x_4-1)(x_1+1)\cdot p_{x_4-1,x_1+1}(t) + \mu_4(x_4+1)\cdot p_{x_4-1,x_1+1}(t)$$

$$+m_{53}(x_5-1)(x_3+1)\cdot p_{x_5-1,x_3+1}(t) + \mu_5(x_5+1)\cdot p_{x_5-1,x_3+1}(t)$$

$$+m_{56}(x_5-1)(x_6+1)\cdot p_{x_5-1,x_6+1}(t) + \mu_5(x_5+1)\cdot p_{x_5-1,x_6+1}(t)$$

$$+m_{63}(x_6-1)(x_3+1)\cdot p_{x_6-1,x_3+1}(t) + \mu_6(x_6+1)\cdot p_{x_6-1,x_3+1}(t)$$

$$+m_{65}(x_6-1)(x_5+1)\cdot p_{x_6-1,x_5+1}(t) + \mu_6(x_6+1)\cdot p_{x_6-1,x_5+1}(t)$$

$$-\begin{bmatrix} 1 + P\pi + (\mu_1+m_{12}+m_{13})(x_1+1) + (\mu_2+m_{23})(x_2+1) \\ +(\mu_3+m_{34}+m_{35}+m_{36})(x_3+1) + (\mu_4+m_{41})(x_4+1) \\ +(\mu_5+m_{53}+m_{56})(x_5+1) + (\mu_6+m_{63}+m_{65})(x_6+1) \end{bmatrix} \cdot p_{x_1,x_2,x_3,x_4,x_5,x_6}(t)$$

$$(2)$$

Equation (2) is a full dynamics and it can be simplified or converted with the aid of multivariate probability generating function. We will then obtain the sets of the following differential equations for expectation below:

$$\frac{dE[X_1(t)]}{dt} = E[P\pi] + m_{41}E[X_4(t)X_1(t)] - m_{12}E[X_1(t)X_2(t)] - m_{13}E[X_1(t)X_3(t)] - \mu E[X_1(t)]$$

$$\frac{dE[X_2(t)]}{dt} = m_{12}E[X_1(t)X_2(t)] - m_{23}E[X_2(t)X_4(t)] - \mu E[X_2(t)]$$

$$\frac{dE[X_3(t)]}{dt} = m_{13}E[X_1(t)X_3(t)] + m_{23}E[X_2(t)X_4(t)] - m_{34}E[X_3(t)X_4(t)] - m_{35}E[X_3(t)X_5(t)] - m_{36}E[X_3(t)X_6(t)] - \mu E[X_3(t)]$$

$$\frac{dE[X_4(t)]}{dt} = m_{34}E[X_3(t)X_4(t)] - m_{41}E[X_4(t)X_1(t)] - \mu E[X_4(t)]$$

$$\frac{dE[X_5(t)]}{dt} = m_{35}E[X_3(t)X_5(t)] + m_{65}E[X_6(t)X_5(t)] - m_{53}E[X_5(t)X_3(t)] - m_{56}E[X_5(t)X_6(t)] - \mu E[X_5(t)]$$

$$\frac{dE[X_6(t)]}{dt} = m_{36}E[X_3(t)X_6(t)] + m_{56}E[X_5(t)X_6(t)] - m_{65}E[X_6(t)X_5(t)] - \mu E[X_6(t)]$$

(6)

(3)

Replacing $X_1 = S$, $X_2 = M$, $X_3 = T$, $X_4 = A$, $X_5 = D$ and $X_6 = C$, the above model expectation equations can also be written as

$$\frac{dS(t)}{dt} = P\pi + m_{41}A(t)S(t) - m_{12}S(t)M(t) - \mu S(t)$$

$$\frac{dM(t)}{dt} = m_{12}S(t)M(t) - m_{23}M(t)T(t) - \mu M(t)$$

$$\frac{dT(t)}{dt} = m_{13}S(t)T(t) + m_{23}M(t)T(t) - m_{34}T(t)A(t) - m_{35}A(t)D(t) - m_{36}T(t)C(t) - \mu T(t)$$

$$\frac{dA(t)}{dt} = m_{34}T(t)A(t) - m_{41}A(t)S(t) - \mu A(t)$$

$$\frac{dD(t)}{dt} = m_{35}T(t)D(t) + m_{65}C(t)D(t) - m_{53}D(t)T(t) - m_{56}D(t)C(t) - \mu D(t)$$

$$\frac{dC(t)}{dt} = m_{36}T(t)C(t) + m_{65}D(t)C(t) - m_{56}C(t)D(t) - \mu C(t)$$

(7)

(4)

3 NUMERICAL SIMULATION

In this section, we analyze the stochastic of terrorism with Counter terrorist strategies. To solve our equation (4), we perform numerical simulation using initial values for state variables and transition parameters in Table 2 below.

Table 2: Parameters/ Variables Description, Source & Value

Variables/Parameters	Description	Value	Source
S	Susceptible Population	10,000	Estimated
M	Moderate Members	50	[5]
T	Terrorist	300	[5]
C	Combatant	80	[5]
D	Detention	20	[5]
R	Rehabilitation	35	[5]
π	Recruitment rate	10	[5]
β_1	Rate at which susceptible moved to Moderate class	0.01	[8]
β_2	Rate at which Moderate moved to Terrorist class	0.2	[8]
σ	Rate at which Terrorist become Combatant	0.3	[5]
δ	Rate of Jail break/Prisoners swap	01	[9]
k	Rate of Surrender Terrorist	0.2	Estimated
r	Rate at which detent member are rehabilitated	0.4	[3]
$1 - \sigma$	Detention due to Counter Terrorist Strategies	0.7	[1]
ω	Radicalization/ rehabilitation rate	0.2	[7]
d	Induced death rate due military operation	0.3	[6]
μ	Natural death of Boko Haram member	0.1	Estimated
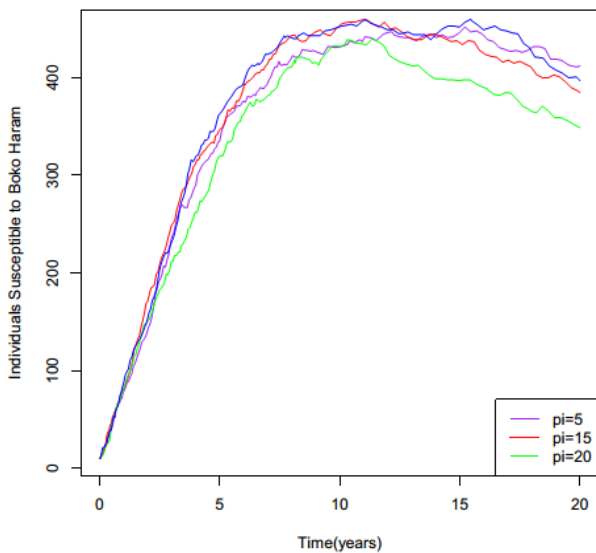
Fig 1: Sample path showing susceptible individuals over time at different values of recruitment rate (Pi).
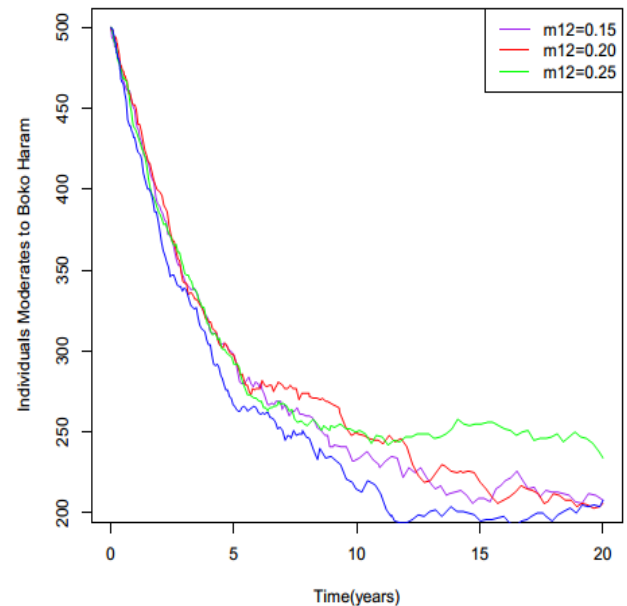
Fig 2: Sample path showing Moderate individuals over time at different values of m_{12}.
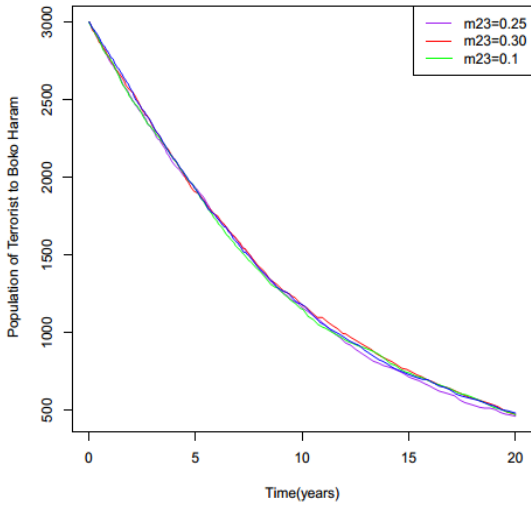
Fig 3: Sample path showing Terrorized individual over time at different values of m_{23}.
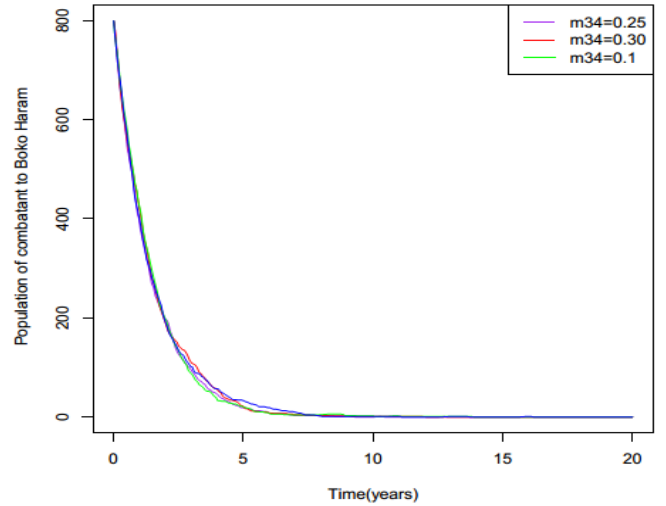
Fig 4: Sample path showing Combatant Terrorist Individual Over time at different values of m_{34}.
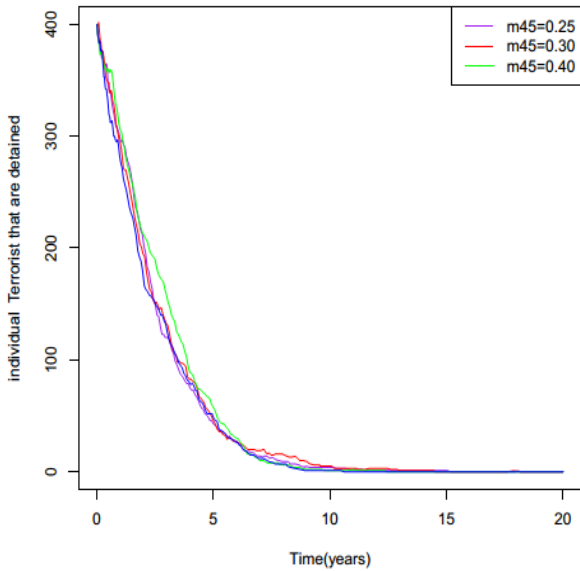
Fig 12: Sample path showing Detained Terrorist individual over time at different values of m_{45}.
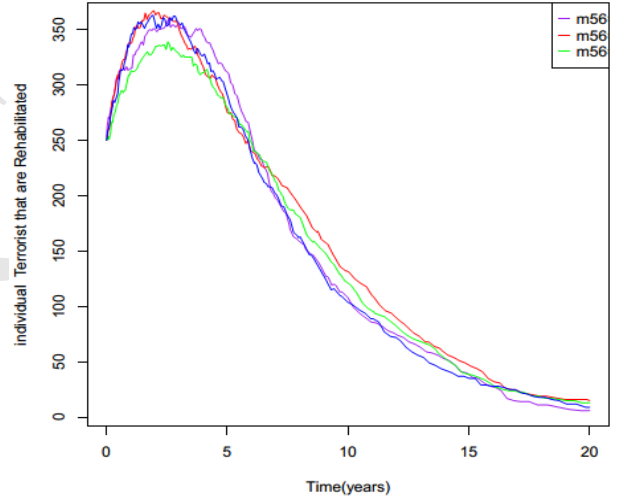
Fig 13: Sample path showing Rehabilitated Terrorist Individual over time at different values of m_{56}.

According to the results shown in **Figure 1,** the number of susceptible individuals, who are at risk of adopting extremist ideologies from the general population, tends to grow exponentially over time. This increase is attributed to their interactions with local communities in search of sympathizers or individuals who can assist them in facilitating attacks and spreading their ideology. In **Figure 2**, it is noted that moderate individuals, who are not actively involved but have some interest in Boko Haram activities due to their connections with terrorists, experience a gradual decline over time. This decline is linked to the interventions of security forces and civilian Joint Task Forces, which monitor and control their potential progression to active membership. **Figure 3** indicates that the number of Boko Haram terrorists is also decreasing over time, primarily due to counter-terrorism operations and the transfer of individuals to detention facilities if they surrender or are captured by military counter-terrorism efforts. The transition to extremism among these individuals is influenced by their interactions with terrorist leaders or combatants. Additionally, **Figure 4** shows that the number of Boko Haram combatants continues to decline over time, again as a result of counter-terrorism operations and the movement of individuals to detention facilities following surrender or capture. **Figure 5** shows the number of detained Boko Haram terrorist.

The detention members tend also decline this was due to high military counter-terrorist activities that accounted for individuals to be imprisoned for life. **Figure 6,** the number of Rehabilitated Boko Haram tends to raises at some point and then later decline over time. This was as a result of the population decreases to natural death and certified repentant terrorist also leave this population to be incorporated back to the society and the certified repentance move from rehabilitation to susceptible.

4 CONCLUSION

We developed and analyzed a stochastic model to understand the dynamics and management of the Boko Haram insurgency in conjunction with counter-terrorism operations. The differential equations that form the basis of the model were established, and simulations were carried out using the available parameters. The results indicated that counter-terrorism strategies have a substantial effect on combating Boko Haram insurgencies. Consequently, we recommend that the Nigerian Army, with significant support from the Air Force, intensify their efforts to overcome the Boko Haram insurgency, including the acquisition of modern weaponry, the establishment of vigilante groups, and the implementation of rehabilitation programs to maintain the defeat of Boko Haram.

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Perturbed Collocation Methods for the Solution of Higher Order Fractional Integro-differential Equations Boundary Value Problems

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Abstract. This article explores the use of two orthogonal polynomial approximation methods to derive numerical solutions for boundary value problems involving higher-order fractional integro-differential equations. We introduce a perturbed collocation approach that transforms these perturbed equations into systems of algebraic equations by employing standard collocation points. The resulting algebraic systems are solved using Newton-Raphson's method, implemented through MAPLE 18 software. Several numerical examples are provided to demonstrate the accuracy and reliability of this method. The findings indicate that the proposed approach is both accurate and efficient. Additionally, the results show a favorable comparison with those obtained by Zhang et al. using the Homotopy Analysis Method.

Keywords: Boundary value problems, Chebyshev polynomials, Fractional derivatives, Perturbation term, Power series polynomials, Perturbed Collocation Method, Newton Raphson method

1 Introduction

Boundary value problems can be effectively approximated using simple and efficient numerical methods. Problems involving the wave equation, such as determining normal modes, are often formulated as boundary value problems. Sturm-Liouville problems represent an important class of boundary value problems, and their analysis involves the eigenfunctions of a differential operator, as discussed by Fu et al.[2].

Zhang et al.[1] employed the Homotopy Analysis Method (HAM) to obtain numerical solutions for higher-order fractional integro-differential equations with boundary value problems. They reported that the numerical results are in good agreement with the exact solution and converge at higher-order approximations. Fadugba [3] presented the Mellin transform approach for solving fractional order equations, which is widely used in applied mathematics and technology. The Mellin transform of various forms of fractional calculus, including the Riemann-Liouville fractional derivative, Riemann-Liouville fractional integral, Caputo fractional derivative, and the Miller-Ross sequential fractional derivative, were obtained.

Methods for solving integro-differential equations typically combine techniques for solving both integral and differential equations. Since closed-form solutions may not be feasible for most applications, numerical methods are employed to obtain approximations to the exact solutions. Abubakar & Taiwo [4], in their thesis "Computational methods for solving system of linear Volterra integral and integro-differential equations," reported the use of successive approximation methods and standard integral collocation to obtain numerical approximations.

Uwaheren et al.[5] developed a perturbed collocation method for solving singular multi-order fractional differential equations of Lane-Emden Type, and found the proposed method to be efficient and yielding good results.

Other methods, such as power series, Chebyshev, and Legendre's polynomials used as basis functions, have been applied to obtain solutions for some higher-order integro-differential equations of both linear and nonlinear types. Akyaz & Sezer [6] used truncated Chebyshev polynomials to obtain approximate solutions of linear integro-differential equations, and the results showed that the method is consistent. Recently, Gelele et al. [7] used power series and Chebychev series approximation methods for solving higher-order linear Fredholm integro-differential equations using collocation methods. The results presented indicated that the method provides accurate results when compared with the exact solution.

Many problems from various sciences and engineering applications can be modeled by fractional integro-differential equations. Furthermore, most of these problems cannot be solved analytically, and finding good approximate solutions using numerical methods will be very helpful, as pointed out by Yang et al.[8]

Several numerical methods have been recently developed to solve fractional differential equations (FDEs) and fractional integro-differential equations (FIDEs). Yang et al. and Mittal & Nigam [8-14] applied collocation methods for solving the following: nonlinear fractional Langevin equation involving two fractional orders in different intervals and fractional Fredholm integro-differential equations. Chebyshev polynomials method is introduced in the literature [10-12] for solving multi-term fractional order differential equations and nonlinear Volterra and Fredholm integro-differential equations of fractional order. Ray [13] applied the variational iteration method for solving fractional integro-differential equations with nonlocal boundary conditions. Adomian decomposition method is introduced in Mittal & Nigam [14] and Wazwaz [15] for solving fractional diffusion equation and fractional integro-differential equations.

In this paper, we present a numerical solution approach for boundary value problems involving higher-order fractional integro-differential equations. To minimize higher error terms, we introduce a perturbation term into the model equation. We then apply Power series and Chebyshev polynomial approximations to derive efficient numerical solutions for the relevant problems. The resulting equations are collocated to form a system of algebraic equations, which allows us to solve for the unknown coefficients.

The structure of the paper is as follows: In Section 2, we introduce preliminary definitions and key properties. Section 3 provides the fundamental definitions and characteristics of power series polynomials and Chebyshev polynomials. In Sections 4 and 5, we apply these polynomials to perturbed higher-order fractional integro-differential equations using the standard collocation method, and we utilize a matrix operation solver to address the resulting systems of equations. Section 6 presents several numerical examples to illustrate the efficiency and accuracy of the proposed algorithm. Finally, we conclude the paper with remarks in Section 7.

Consider the general form of fractional integro-differential equation boundary value problems with Caputo derivative defined in Zhang [1] as follows

$$
{}_a^C D_t^\alpha u(t) = f(t) + \gamma u(t) + \lambda \int_a^b k(t,s) u(s) ds, \tag{1}
$$

subject initial-boundary conditions

$$
u^{(i)}(a) = \mu_i, u^{(i)}(b) = \eta_i, i = 0(1)n \tag{2}
$$

Where is the Caputo fractional derivative of order are given continuous smooth functions, is the unknown function to be determined, and are real constants.where ${}_a^C D_t^\alpha$ is the Caputo fractional derivative of order α, $f(t), k(t,s)$ are given continuous smooth functions, $u(s)$ is the unknown function to be determined, and a, b, λ, γ are real constants.

2 Preliminaries

Here, we give some basic definitions, theorem and properties of fractional calculus theory that can be used in understanding this paper.

Definition 2.1: The most common fractional operators are the Riemann-Liouville Fractional Integral (RLFI), the Riemann-Liouville Fractional Derivative (RLFD) and the Caputo Fractional Derivative (CFD) which are defined as follows:

Let $x : [a, b] \to R$ be a function, let $\alpha > 0$ be a real number, and let $n = \lceil \alpha \rceil$, where α denotes the smallest integer greater than or equal to α. For $t \in [a, b]$, defined

$$_a I_t^\alpha x(t) = \frac{1}{\Gamma(\alpha)} \int_a^t (t - \tau)^{\alpha - 1} x(\tau) d$$

$$_t I_b^\alpha x(t) = \frac{1}{\Gamma(\alpha)} \int_t^b (\tau - t)^{\alpha - 1} x(\tau) d$$

$$_a D_t^\alpha x(t) = \frac{1}{\Gamma(n - \alpha)} \frac{d^n}{dt^n} \int_a^t (t - \tau)^{n - \alpha - 1} x(\tau) d\tau$$

$$_t D_b^\alpha x(t) = \frac{(-1)^n}{\Gamma(n - \alpha)} \frac{d^n}{dt^n} \int_t^b (\tau - t)^{n - \alpha - 1} x(\tau) d\tau$$

$$_a^C D_t^\alpha x(t) = \frac{1}{\Gamma(n - \alpha)} \int_a^t (t - \tau)^{n - \alpha - 1} x^{(n)}(\tau) d\tau$$

$$_t^C D_b^\alpha x(t) = \frac{(-1)^n}{\Gamma(n - \alpha)} \int_t^b (\tau - t)^{n - \alpha - 1} x^{(n)}(\tau) d\tau$$

where $n = \lceil \alpha \rceil + 1$ for the definitions of Riemann-Liouville fractional derivatives, and for the Caputo fractional derivatives.

Definition 2.2: Let the function $\Gamma : (0, \infty) \to R$, defined by

$$\Gamma(n) := \int_0^\infty e^{-t} t^{n-1} dt, n > 0. \tag{3}$$

Definition 2.3: Beta function is defined in terms of gamma function as

$$B(n, m) = \int_0^1 t^{n-1} (1 - t)^{m-1} dt = \frac{\Gamma(n) \Gamma(m)}{\Gamma(n + m)}, n, m \in R^+. \tag{4}$$

Theorem 2.1: Let $\Phi \in H_\mu[a,b]$ for some $\mu \in [0,1]$ and let $0 < n < 1$. Then

$$J_a^\alpha \Phi(t) = \frac{\Phi(a)}{\Gamma(\alpha+1)}(x-a)^\alpha + \Psi(t), \tag{5}$$

with some function $\Psi(t) = O\left((x-a)^{\mu+\alpha}\right)$.

3 Polynomial Approximate solutions

An approximate solution of the truncated Chebyshev and Power series orthogonal polynomials can be used to obtain the approximations of (1) and (2) as defined in the form

$$u_n(t) = \sum_{i=0}^n a_i \Phi_i(t), 0 < n < \infty. \tag{6}$$

and

$$\Phi_i(t) = \begin{cases} P_i(t) \\ T_i(t) \end{cases}, \tag{7}$$

where τ is the unknown to be determined and $P(t)$ and $T(t)$ are power series and Chebyshev orthogonal polynomials respectively.

The $r - th$ degree chebyshev polynomial of the first kind valid in [a,b] is defined as

$$T_r(x) = \cos\left\{r\cos^{-1}\left(\frac{2x-2a}{b-a}-1\right)\right\} \equiv \sum_{k=0}^r C_k^{(r)} x^k, \tag{8}$$

with

$$C_r^{(r)} = 2^{2r-1}(b-a)^r. \tag{9}$$

For this purpose, we consider $a = 0$ and $b = 1$, so that (8) becomes

$$T_r(x) = \cos\{r\cos(2x-1)\} \equiv \sum_{k=0}^r C_k^{(r)} x^k, \tag{10}$$

$$T_0(x) = 1, T_1(x) = (2x-1) \tag{11}$$

This satisfies the recurrence relation

$$T_{r+1} = 2(2x-1)T_r(x) \quad T_{r-1}(x), r = 1,2,3,\ldots \tag{12}$$

4 Perturbed Collocation Method by Power Series

Sequel to the theorem 2.1, we established the following corollary

Corollary 3.1 Let $Q([t_0, t_f], R)$ be defined by $Q(s) = (s-t_0)^\beta$ for some $\beta > -1$ and $\alpha > 0$, and let $\alpha, \beta \in R_+$ and $s \in [t_0, t_f]$. Then,

$$\frac{1}{\Gamma(1-\alpha)}\int_{t_0}^t (t-s)^{-\alpha} Q(s) ds = \frac{\Gamma(\beta+1)}{\Gamma(1-\alpha+\beta)}(t-t_0)^{\alpha+\beta}. \tag{13}$$

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Proof: Using left Caputo fractional derivative for $n = 1$, we have

$$
{}^{C}_{t_0} D^{\alpha}_{t} Q(s) = \frac{1}{\Gamma(1-\alpha)} \int_{t_0}^{t} (t-s)^{-\alpha} Q'(s) ds \tag{14}
$$

Substituting $Q'(s) = \beta(s-t_0)^{\beta-1}$ into (14), to obtain

$$
\frac{1}{\Gamma(1-\alpha)} \int_{t_0}^{t} (t-s)^{-\alpha} \beta(s-t_0)^{\beta-1} ds. \tag{15}
$$

Let $x = \dfrac{(s-t_0)}{(t-t_0)}$, so that $s = x(s-t_0) + t_0$ and $(t-t_0)dx = ds$, then

$$
\frac{1}{\Gamma(1-\alpha)} \qquad = \int_{t_0}^{t} (t-s)^{-\alpha} \beta(s-t_0)^{\beta-1} ds \tag{16}
$$

$$
\frac{\beta}{\Gamma(1-\alpha)} \qquad = \int_{0}^{1} [(t-t_0) - x(t-t_0)]^{-\alpha} [x(t-t_0)]^{\beta-1} (t-t_0) dx
$$

$$
\frac{\beta(t-t_0)^{-\alpha+\beta}}{\Gamma(1-\alpha)} \qquad = \int_{0}^{1} (1-x)^{-\alpha} x^{\beta-1} dx.
$$

Using Beta function $\displaystyle\int_{0}^{1} (1-t)^{\alpha-1} t^{\beta-1} dt = \frac{\Gamma(\alpha)\Gamma(\beta)}{\Gamma(\alpha+\beta)}$, we have

$$
\frac{1}{\Gamma(1-\alpha)} \int_{t_0}^{t} (t-s)^{-\alpha} (s-t_0)^{\beta-1} ds = \frac{\Gamma(\beta+1)}{\Gamma(1-\alpha+\beta)} (t-t_0)^{-\alpha+\beta}. \tag{17}
$$

$\square$

Now considering equation (1) together with the perturbation term of the form

$$
{}^{C}_{a} D^{\alpha}_{t} u_n(t) = f(t) + \gamma u_n(t) + \lambda \int_{a}^{b} k(t,s) u_n(s) ds + H_n(t), \tag{18}
$$

where $a < t < b$,

$$
H_n(t) = \sum_{r=0}^{n-1} \tau_{m-r} T_{n\ m+r+1}(t) \tag{19}
$$

Now, substituting (6) into (18) and simplify to obtain

$$D_t^\alpha\left(a_0 + a_1 t + a_2 t^2 + a_3 t^3 + \ldots + a_n t^n\right) = f(t) \tag{20}$$

$$+ \gamma\left(a_0 + a_1 t + a_2 t^2 + a_3 t^3 + \ldots + a_n t^n\right)$$

$$+ \lambda\int_a^b k(t,s)\left(a_0 + a_1 s + a_2 s^2 + a_3 s^3 + \ldots + a_n s^n\right)ds$$

$$+ \tau_1 T_n(t) + \tau_2 T_{n\ 1}(t) + \tau_3 T_{n\ 2}(t) + \ldots$$

simplifying (20) further to obtain

$$\left(\frac{\Gamma(n+1)}{\Gamma(1-\alpha+n)}t^{n-\alpha} - \gamma - \lambda\int_a^b k(t,s)ds\right)a_0 \tag{21}$$

$$+ \left(\frac{\Gamma(n+1)}{\Gamma(1-\alpha+n)}t^{n-\alpha} - \gamma t - \lambda\int_a^b k(t,s)s\,ds\right)a_1$$

$$+ \left(\frac{\Gamma(n+1)}{\Gamma(1\ \alpha+n)}t^{n\ \alpha}\quad \gamma t^2 \quad \lambda\int_a^b k(t,s)s^2 ds\right)a_2$$

$$+ \left(\frac{\Gamma(n+1)}{\Gamma(1-\alpha+n)}t^{n-\alpha} - \gamma t^3 - \lambda\int_a^b k(t,s)s^3 ds\right)a_3$$

$$+ \ldots + \left(\frac{\Gamma(n+1)}{\Gamma(1-\alpha+n)}t^{n-\alpha} - \gamma t^n - \lambda\int_a^b k(t,s)s^n ds\right)a_n$$

$$\tau_1 T_n(t) - \tau_2 T_{n\ 1}(t) - \tau_3 T_{n\ 2}(t) - \ldots = f(t)$$

Therefore, the time interval $[a,b]$ is divided into N equally spaced (sub-intervals). Let $t_j = a + hj$, where $h = \dfrac{b-a}{N}$ and $j = 0(1)N$, then, there is need to construct the associated system of algebraic equations in a manner that require less computational time and give efficient results.

Now, collocating (21) at the node of t_j, we have

$$\left(\frac{\Gamma(n+1)}{\Gamma(1-\alpha+n)} t_j^{n-\alpha} - \gamma - \lambda \int_a^b k(t,s_j)s\,ds \right)a_0 \qquad (22)$$

$$+ \left(\frac{\Gamma(n+1)}{\Gamma(1-\alpha+n)} t_j^{n-\alpha} - \gamma t_j - \lambda \int_a^b k(t,s_j)s_j\,ds \right)a_1$$

$$+ \left(\frac{\Gamma(n+1)}{\Gamma(1-\alpha+n)} t_j^{n-\alpha} - \gamma t_j^2 - \lambda \int_a^b k(t,s_j)s_j^2\,ds \right)a_2$$

$$+ \left(\frac{\Gamma(n+1)}{\Gamma(1-\alpha+n)} t_j^{n-\alpha} - \gamma t_j^3 - \lambda \int_a^b k(t,s_j)s_j^3\,ds \right)a_3$$

$$+ \ldots + \left(\frac{\Gamma(n+1)}{\Gamma(1-\alpha+n)} t_j^{n-\alpha} \quad \gamma t_j^n \quad \lambda \int_a^b k(t,s_j)s_j^n\,ds \right)a_n$$

$$\tau_1 T_n(t_j) - \tau_2 T_{n-1}(t_j) - \tau_3 T_{n-2}(t_j) - \ldots = f(t_j).$$

Thus (21) gives rise to (N+3) algebraic linear equations in (N+3) unknown constants $(a_0, a_1, \ldots, a_N, \tau_1, \tau_2, \tau_3, \ldots)$ together with the extra equations obtained from the boundary conditions. Altogether, we have (N+3) algebraic linear equations in (N+3) unknown constants which are then solved by Maple 18 software to obtain the values of the unknown constants.

5 Perturbed Collocation Method by Chebyshev Polynomials

In order to apply this method, we substitute an approximate solution (6) into a slightly perturbed equation (18) to gives

$$D_t^\alpha (a_0 T_0(t) + a_1 T_1(t) + a_2 T_2(t) + a_3 T_3(t) + \ldots + a_n T_n(t)) = f(t) \qquad (23)$$

$$+ \gamma(a_0 T_0(t) + a_1 T_1(t) + a_2 T_2(t) + a_3 T_3(t) + \ldots + a_n T_n(t))$$

$$+ \lambda \int_a^b k(t,s)(a_0 T_0(s) + a_1 T_1(s) + a_2 T_2(s) + \ldots + a_n T_n(s))\,ds$$

$$+ \tau_1 T_n(t) + \tau_2 T_{n-1}(t) + \tau_3 T_{n-2}(t) + \ldots$$

simplifying (23) further to obtain

$$\left(\frac{\Gamma(n+1)}{\Gamma(1-\alpha+n)} T_0^{n-\alpha}(t) - \gamma T_0(t) - \lambda \int_a^b k(t,s) T_0(s) ds \right) a_0 \qquad (24)$$

$$+ \left(\frac{\Gamma(n+1)}{\Gamma(1-\alpha+n)} T_1^{n-\alpha}(t) - \gamma T_1(t) - \lambda \int_a^b k(t,s) T_1(s) ds \right) a_1$$

$$+ \left(\frac{\Gamma(n+1)}{\Gamma(1-\alpha+n)} T_2^{n-\alpha}(t) - \gamma T_2(t) - \lambda \int_a^b k(t,s) T_2(s) ds \right) a_2$$

$$+ \left(\frac{\Gamma(n+1)}{\Gamma(1-\alpha+n)} T_3^{n-\alpha}(t) \quad \gamma T_3(t) - \lambda \int_a^b k(t,s) T_3(s) ds \right) a_3$$

$$+ \ldots + \left(\frac{\Gamma(n+1)}{\Gamma(1-\alpha+n)} T_0^{n-\alpha}(t) \quad \gamma T_n(t) \quad \lambda \int_a^b k(t,s) T_n(s) \right) a_n$$

$$\tau_1 T_n(t) - \tau_2 T_{n-1}(t) - \tau_3 T_{n-2}(t) - \ldots = f(t)$$

Now, collocating (24) at the node of t_j, we have

$$\left(\frac{\Gamma(n+1)}{\Gamma(1-\alpha+n)} T_0^{n-\alpha}(t_j) - \gamma T_0(t_j) - \lambda \int_a^b k(t,s_j) T_0(s_j) ds \right) a_0 \qquad (25)$$

$$+ \left(\frac{\Gamma(n+1)}{\Gamma(1-\alpha+n)} T_1^{n-\alpha}(t_j) - \gamma T_1(t_j) - \lambda \int_a^b k(t,s_j) T_1(s_j) ds \right) a_1$$

$$+ \left(\frac{\Gamma(n+1)}{\Gamma(1-\alpha+n)} T_2^{n-\alpha}(t_j) - \gamma T_2(t_j) - \lambda \int_a^b k(t,s_j) T_2(s_j) ds \right) a_2$$

$$+ \left(\frac{\Gamma(n+1)}{\Gamma(1-\alpha+n)} T_3^{n-\alpha}(t_j) - \gamma T_3(t_j) - \lambda \int_a^b k(t,s_j) T_3(s_j) ds \right) a_3$$

$$+ \ldots + \left(\frac{\Gamma(n+1)}{\Gamma(1-\alpha+n)} T_n^{n-\alpha}(t_j) \quad \gamma T_n(t_j) \quad \lambda \int_a^b k(t,s_j) T_n(s_j) ds \right) a_n$$

$$- \tau_1 T_n(t_j) - \tau_2 T_{n-1}(t_j) - \tau_3 T_{n-2}(t_j) - \ldots = f(t_j).$$

6 Numerical Examples

Problem 1: Consider the Fractional order integro-differential equation defined by Zhang et al [1]. as

$$D_t^\alpha u(t) = t(1+e^t) + 3e^t + u(t) \int_0^t u(s)ds, 0 < t < 1, 3 < \alpha \le 4, \qquad (26)$$

subject to boundary conditions

$$u(0) = 1, u'(0) = 2, u(1) = 1 + e, u'(1) = 3e. \qquad (27)$$

Comparing with equations (1) and (2), we have

$$f(t) = t(1+e^t) + 3e^t, \gamma = 1, \lambda = 1, k(t,s) = 1, \mu_0 = 1, \mu_2 = 2, \eta_0 = 1 + e \text{ and } \eta_2 = 3e. \quad (28)$$

Therefore, consider forth degree $(n = 4)$ approximation, we have from approximate solution

$$u_4 = \sum_{i=0}^{4} a_i t^i = a_0 + a_1 t + a_2 t^2 + a_3 t^3 + a_4 t^4. \qquad (29)$$

Using power series polynomial approximate solution, we substitute equation (26) into collocation equation (25), and together with the extra equations obtained from boundary conditions, gives the following matrix equation of the form $Ax = b$ as

$$\begin{pmatrix}
0.50000 & 0.2500 & -0.83333 & -0.25000 & -2986.45073 & 0.33333 & -0.43321 & 0.55321 & 0.75321 \\
0.87500 & 0.12500 & -0.73333 & -0.25000 & -3986.45073 & 0.33300 & -0.43320 & 0.55320 & 0.75320 \\
0.95000 & 0.56500 & -0.53333 & -0.85000 & -4986.45073 & 0.63300 & -0.63300 & 0.65320 & 1.00000 \\
0.98500 & 0.25000 & -0.73333 & -0.72545 & -5986.45073 & 0.67300 & -0.43320 & 0.89532 & 0.65532 \\
0.54500 & 0.67250 & -0.33300 & -0.725070 & -6986.45070 & 0.73300 & -0.87300 & 0.45500 & 0.24500 \\
1 & -1 & 1 & -1 & 1 & 0 & 0 & 0 & 0 \\
1 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 16 & -96 & 320 & 0 & 0 & 0 & 0 \\
0 & 0 & 16 & 96 & 320 & 0 & 0 & 0 & 0
\end{pmatrix}$$

$$\begin{pmatrix} a_0 \\ a_1 \\ a_2 \\ a_3 \\ a_4 \\ \tau_1 \\ \tau_2 \\ \tau_3 \\ \tau_4 \end{pmatrix} = \begin{pmatrix} -6.70524 \\ -8.07055 \\ -9.17052 \\ -13.25245 \\ -17.37052 \\ 1 \\ 1+e \\ 2 \\ 3e \end{pmatrix}$$

Again, consider sixth degree $(n = 6)$ approximation, we have from approximate solution

$$u_6 = \sum_{i=0}^{6} a_i t^i = a_0 + a_1 t + a_2 t^2 + a_3 t^3 + a_4 t^4 + a_5 t^5 + a_6 t^6. \qquad (30)$$

Using Chebyshev polynomial approximate solution, we substitute equation (28) into collocation equation (25), and together with the extra equations obtained from boundary conditions, gives also the system of equation of the form $Ax = b$.

Problem 2: Consider the Fractional order integro-differential equation defined by Zhang et al [1]. as

$$D_t^\alpha u(t) = 1 + (5+t)e^t + u(t) \int_0^t u(s)ds, 0 < t < 1, 5 < \alpha \le 6, \qquad (31)$$

subject to boundary conditions

$$u(0) = 0, u'(0) = 2, u^{(iv)}(0) = 4, u(1) = e, u'(1) = 3e u^{(iv)} = 5e. \qquad (32)$$

Comparing with equations (1) and (2), we have $f(t) = 1 + (5+t)e^t, \gamma = 1, \lambda = 1, k(t,s) = 1, \mu_0 = 0, \mu_2 = 2, \mu_4 = 4, \eta_0 = 1+e, \eta_2 = 3e$ and $\eta_4 = 5e$.

6 Conclusion

This article presents a numerical solution approach for higher-order fractional integro-differential equations with boundary value problems. Our methods are based on Power series polynomial and Chebyshev polynomial approximations, which reduce the perturbed higher-order fractional integro-differential equation to a set of linear algebraic equations. These equations can be easily solved using the standard collocation method and computer implementation. The results obtained demonstrate that both the Power series polynomial and Chebyshev polynomial methods can effectively handle these types of problems, as evident from the tables of results. The findings compare favorably with the work of Zhang et al. [1], who used the Homotopy Analysis Method. In the first problem, varying the order of α and β and the degree of approximations from 4 up to 6 shows that as the degree of approximation increases, the accuracy of the results improves. Similarly, in the second problem, the results obtained at higher degrees of approximation yield better outcomes. For future studies, we plan to investigate further the existence and uniqueness of perturbed fractional integro-differential equations with boundary value problems. Additionally, we aim to consider the numerical solution of systems of these problems. We welcome comments and feedback from fellow readers to enhance our research.

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Dual-Band Slotted Millimeter Wave Antenna at 28/38 GHz for 5G Applications

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Abstract - Modern communication systems enable the rapid development of microstrip patch antennas. Their lightweight and compact profile makes patch antennas increasingly popular today. They are easy to manufacture and seamlessly integrate into feeding networks, making them highly versatile for modern applications. This paper presents a single-feed, dual-band slotted antenna designed for 5G applications, operating in the 28 GHz and 38 GHz millimeter-wave bands with enhanced bandwidth. The antenna design uses a Rogers 5880 substrate with a relative permittivity of 2.2 and a loss tangent of 0.0009, modeled with CST software. The microstrip antenna measures 20 x 20 x 0.787 mm³ and features a cylindrical patch on top, with inner and outer radii of 3.00 mm and 4.32 mm, and a thickness of 0.787 mm. Initially, a cylindrical radiator is configured to resonate at 38 GHz; subsequently, a symmetrical four-cone slot is introduced on the cylindrical radiator to enable an additional resonant frequency at 28 GHz. Simulation results indicate reflection coefficients of -27.83 dB at 28 GHz and -49.47 dB at 38 GHz, with achieved bandwidths of 0.765 GHz in the lower band and 1.29 GHz in the upper band, and gains of 7.52 dBi and 6.67 dBi, respectively.

Keywords— four cone slots, 5G, Cylindrical Shape and millimeter wave.

1 INTRODUCTION

Antennas for fifth-generation (5G) wireless communication have recently attracted considerable interest [1]-[3]. Millimeter-wave (mmWave) antennas play a critical role in 5G applications due to their capabilities for high-speed, low-latency data transmission, and increased data rates. With the rapid growth of internet applications driving demand for higher data rates and expanded bandwidth, researchers are exploring new frequency bands to support the future of wireless communication technologies [4]. Numerous studies investigate various mmWave antenna designs to meet these demands [5]-[8].

The 5G Partnership Project has standardized several frequency bands to optimize 5G performance, including 28 GHz, 38 GHz, and 60 GHz, each tailored for specific applications. Consequently, patch antennas with single, dual, or multiband configurations are needed to accommodate these frequencies [4-9]. The FCC has allocated the 28 GHz, 37 GHz, 39 GHz, and 64–71 GHz bands specifically for 5G use [10]. Among these, the 28 GHz and 38 GHz frequencies are particularly prevalent in next-generation mmWave communication systems for 5G applications [9]. A dual-band antenna capable of operating at both 28 GHz and 38 GHz is highly beneficial for a range of applications [10-14]. In [6], a copper-tapered slot antenna with a simple design is proposed, covering the 24.25–28.35 GHz range. Another study [4] introduces an antenna with a U-slot in the ground plane to achieve a broader bandwidth for 5G mmWave applications, though its bandwidth is still limited and does not fully encompass the 28 GHz and 38 GHz mmWave bands. In [15], a four-element dual-mode planar monopole antenna, measuring 20 × 20 mm², offers a moderate bandwidth of 1.75 GHz in the lower band. According to references [21-25], the desired bandwidth for a dual-band antenna is approximately 1.9%

at 38 GHz and 3% at 28 GHz. Reference [12] describes a 5G dipole antenna with a broad bandwidth ranging from 26.5 to 38.2 GHz and an approximate gain of 5 dBi. In [13], an antenna that operates at 24 GHz and 28.5 GHz achieves gains of 3.5 dBi and 4 dBi at these frequencies, respectively. A microstrip patch antenna in [14] provides a bandwidth of 1.3 GHz at 28 GHz and 1 GHz at 45 GHz, with gains of 7.6 dBi and 7.21 dBi, respectively. Reference [15] introduces a dual-band antenna operating at 28 GHz and 38 GHz, achieving bandwidths of 1.43 GHz and 3.54 GHz and gains of 2.7 dBi and 6 dBi, respectively. Additionally, an H-shaped slot dual-band patch antenna in [16] provides bandwidths of 3.2 GHz at 28 GHz and 5.3 GHz at 38 GHz, with gains of 8.4 dBi and 6.1 dBi, respectively. In [17], a novel rectangular dielectric resonator antenna is described for 5G applications, offering operation at 28 GHz and 38 GHz with bandwidths of 1.49 GHz and 1.01 GHz and gains of 5.41 dBi and 4.89 dBi, respectively. In [18], discusses a dual-band microstrip antenna with a defected ground structure (DGS), which achieves a bandwidth of 4.1 GHz and a gain of 6 dBi at both 28 GHz and 38 GHz. Various other studies [19-22] present dual-band antennas designed for 28 GHz and 38 GHz operation, each offering distinct bandwidth and gain characteristics tailored to specific applications. In [23], a notched antenna design is created by introducing a cut in the feed line, which enables effective radiation in the 30-34 GHz range while maintaining functionality at both 28 GHz and 38 GHz.

Dual-band antennas are typically favored over single-band designs due to their broader bandwidth and versatility in supporting multiple frequencies. This paper introduces a novel 5G antenna operating at 28 GHz and 38 GHz, incorporating a distinctive cross-shaped structure with four cone-shaped slots at the center of a cylindrical patch, which greatly enhances both bandwidth and gain.

This work presents a dual-band slotted millimeter-wave (mmWave) microstrip antenna with a symmetrical four-cone slot configuration, enabling efficient operation at both 28 GHz and 38 GHz frequency bands. The antenna design was modeled and simulated in CST Microwave Studio software, yielding detailed performance data that validate the proposed design's effectiveness in achieving the targeted dual-band functionality.
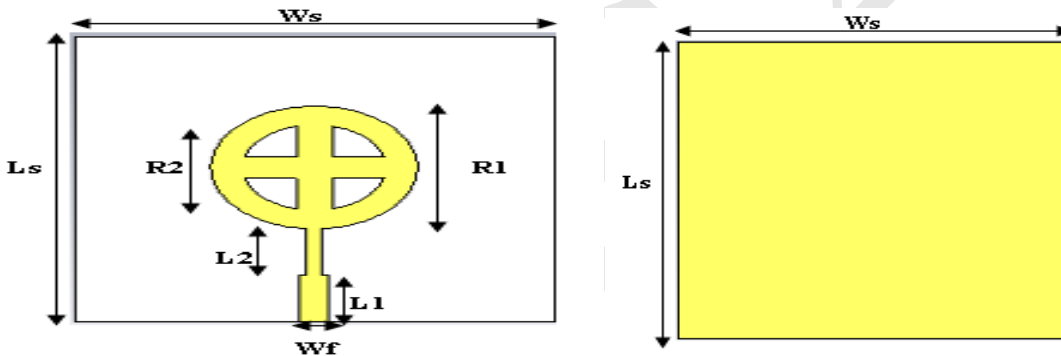
Fig. 1. The Proposed Dual Band Antenna Schematic Diagram (Front and back view)

The proposed dual-band antenna was initially designed to operate at 38 GHz. To achieve a second operational frequency at 28 GHz, a cross structure was introduced, creating four core slots at the center of a cylindrical patch, as illustrated in Fig. 1 above. This addition enables the antenna to effectively cover both 28 GHz and 38 GHz frequency bands, enhancing its versatility for dual band 5G applications.

TABLE I.   VALUE OF THE PROPOSED DESIGN PARAMETERS

Parameter.	Wf	L1	L2	Ws	Ls
Values in (mm)	1.23	3.3	3.21	20	20
Parameter.	R1	R2			
Values in (mm)	4.32	3.0			

2   SIMULATION RESULTS

The prototype antenna has dimensions of $L \times L = 20 \times 20$ mm^2. It is built using Rogers RT 5880 substrate material, which has a thickness h = 0.787 mm and a dielectric constant Er = 2.2. To achieve a multi-mode resonance feature, a symmetrical design with four cone-shaped slots is introduced. The dual-band antenna design process involves two

primary stages, as illustrated in Figure 1. In the first stage, a cylindrical antenna patch is created with an outer radius R1 = 4.32 mm and an inner radius R2 = 3.0 mm. Through parametric sweeps, this configuration achieves an initial resonance frequency at 38 GHz. A 50Ω microstrip line is used to feed the patch, with a width Wf = 1.23 mm and length Lf = 3.3 mm. In the second stage, to introduce a second resonance mode at 28 GHz, a cross-shaped structure is added to the center of the cylindrical patch, forming four cone-shaped slots. This additional structure enables dual-band operation by producing the desired second resonance mode. The antenna design is simulated in CST to analyse the reflection coefficient. The resulting design achieves two operational frequency bands, as shown in the figure 1, one centered around 28 GHz and the other around 38 GHz. The bandwidths for |S₁₁| < -10 dB are 0.765 GHz covering from 27.473—28.238 GHz band as well as 1.29 GHz covering from 37.356—38.646 GHz band, making the antenna suitable for recent 5G applications.
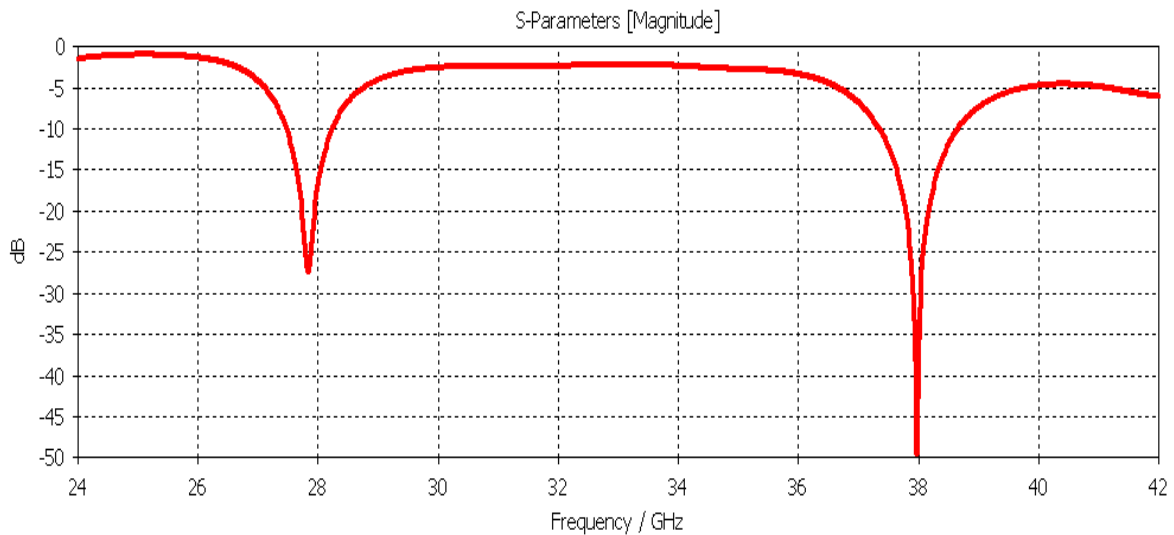
Fig. 2. The Reflection Coefficient of the Proposed Dual-Band Slotted Antenna.

The radiation patterns of the designed antenna are evaluated through numerical simulations. Figure 3 presents the 3D radiation patterns at the operating frequencies of 28 GHz and 38 GHz, llustrating the antenna's performance in terms of directionality and gain at these frequencies.

Fig. 3. The 3-D Radiation Patterns (a) f=28 GHz (b) f=38 GHz
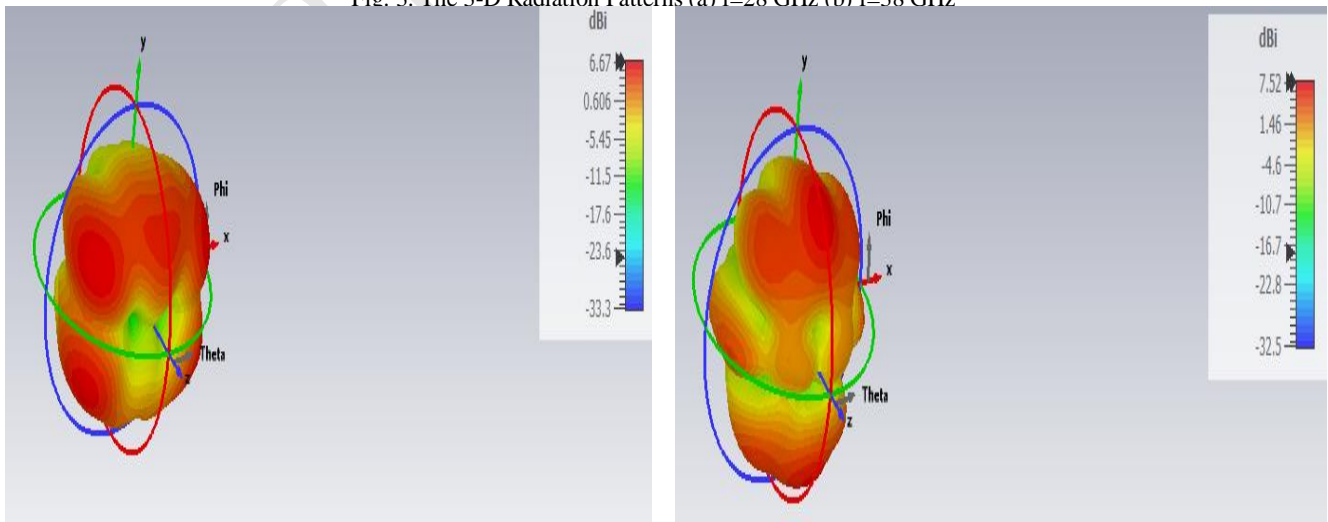
3   CONCLUSIONS

This paper presents an enhanced dual-band millimeter-wave slotted antenna designed for 5G mobile networks. The resulting dual-band microstrip patch antenna operates at 27.29 GHz and 37.97 GHz, achieving S_{11} values of -27.8 dB and -49.47 dB, respectively. The antenna's design begins with a cylindrical patch intended to resonate at 38 GHz. To introduce a second resonance at 28 GHz, a cross-shaped structure is added at the center, creating four symmetrical cone-shaped slots in the cylindrical patch. This dual-resonance structure is fabricated on a Rogers 5880 substrate with a thickness of 0.787 mm and a dielectric constant of 2.2. Initially, the antenna is configured to resonate at 38 GHz. Then, by adding the cone-shaped slots at the center of the cylindrical radiator, a secondary resonance at 28 GHz is achieved. The design attains a maximum directivity of 6.67 dBi at 28 GHz and 7.52 dBi at 38 GHz. The -10 dB impedance bandwidths for each band are 0.756 GHz and 1.29 GHz, making this antenna suitable for dual-band operation in modern 5G applications.

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The Role of Mathematics Teachers in an Inclusive Education: Implication for Combating Security Issues in the North-East of Nigeria.

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Abstract

In many African countries including Nigeria, the citizens are still looking forward to good security as there is a clear absence of the essential attributes of good security. Mathematics is a veritable tool for the solution for all human problems including the problem of security in societies. Therefore, the paper discusses the role of Mathematics teachers in an inclusive Education: Implication for combating security issues in the country. This paper focuses on the concept of Mathematics Teachers, Inclusive Education, and combating security issues. The paper recommends that Mathematics Teachers should prepare students to identify and analyse the applications of Mathematics in addressing social problems including the problems of insecurity in the country. Serving Mathematics teachers should be made to update themselves through in-service training, workshops, seminars and conferences. Furthermore, government / non-government organizations NGOswho design and plan inclusive Education programmes and services should make the recruitment of quality mathematics teachers a priority alongside adequate incentives and job security to motivate them to discharge their work effectively, if the Nation desires a possible change in eradicating insecurity to enhance sustainable development.

Keywords: Role, Mathematics Teachers, Inclusive Education, Combating Security.

1 Introduction

It is good for all students to live and study together in unity despite the special needs of others. Students depend on each other in virtually every activity directed towards the satisfaction of mankind Olajide,(2021). The ultimate aspiration of every Nation to attain optimum development in all facets of life which would necessitate the desired change is paramount in Nigeria. The National Policy on Education (NPC) (2013 revised) left no one in doubt about the interaction of the Nigerian government in ensuring that everybody should be educated at least from the lower and upper basic levels. No wonder, Okeke, cited in Lere (2014) pointed out that Nigeria is a country in search of development and that development is realizable through general education.

Given the fast-growing technologically and scientifically engineered society of today, Mathematics is a very important subject In that regard. It is relevant to every country's national development. Mathematics is a highly structured and important subject and its teaching and learning deserve the highest level of seriousness from teachers to meet the desired national goals. A regular mathematics teacher has been trained and certificated with mathematics skills to impart knowledge or teach both the able and disabled in a regular classroom situation. The revised national policy on Education (2013) focuses on inclusive Education of children and youths with special needs in regular schools. The particular philosophy has involved the fact that students have the right to receive Education without bias to their disability, ethnicity, religion, Language, gender or capabilities.

The policy of inclusive Education involved several other international documents of which Nigeria is a signatory. Such documents include amongst others the Convention Rights of the Child (1989) on the World Declaration of Education for All (EFA)(1990) pertinent to those government policies, one may ask whether Mathematics teachers handling inclusive classrooms have specific roles since the able and disabled are taught together in Nigeria for national development. The paper in its discussion looks at the concepts of Mathematics Teachers, Inclusive Education, and combating security issues. It is, therefore, the concern of this paper to highlight the role of Mathematics teachers in inclusive Education To combat security issues in Nigeria.

2 The Concept of Mathematics Teacher

Kurumeh (2011) defines a Mathematics Teacher as an individual who systematically presents mathematics facts, ideas skills and techniques to learners to impact new experiences to them. Odogwu & Odafe (2013) define a mathematics teacher as a purposeful leader who impacts mathematics information or skills to another individual or a group of individuals. Therefore, a Mathematics Teacher organizes mathematics learning experiences and a conducive environment where learning can conveniently take place. Mathematics is compulsory for secondary school students, so it must be taught in an inclusive classroom too. Kurumeh (2011) outlined amongst others some of the qualities of a good mathematics teacher for effective handling of Mathematics Teaching in an inclusive situation:

1. He must be a leader who can inspire and influence students through expert and referent power.
2. He must be a model of enthusiasm not only for his subject but also for teaching and learning in general.
3. He must be an innovator who changes teaching strategies, techniques, texts and materials when better ones are found.
4. He must know his student's capabilities in terms of abilities.
5. He must be a collaborator who places high value on the experiences of skills and knowledge to be imparted to learners.

2.1 The Meaning of Inclusive Education.

Olajide (2012) defines inclusive Education as the education process that provides opportunity, access and the enabling environment for all children to be equitably educated without segregation or discrimination irrespective of their perceived abilities. The author said that in an inclusive classroom, there is a range of students with abilities and disabilities and this calls for a variety of programme personnel to take care of the various needs of the students.

The advocates of inclusive Education are of the view that every child has the right to education in the neighbourhood schools where they will be taught with non-disabled peers in the classroom Chukuka (2014). Lere (2014) stresses the philosophy of inclusive Education as a process where teachers accept every learner in a regular classroom irrespective of his or her body condition, race or religion for instruction and learning. It is the type of education in a regular school environment or classroom that is devoid of segregation and isolation of pupils' situation.

Inclusive Education is new in Nigeria because many teachers are not comfortable with the idea of including children with special needs in a regular classroom while only a few admit open education right from Early childhood is commendable and that integration of all children in society is the target Jatau & Wadak (2012). Indeed, in inclusive Education, all students are educated in the same classroom with the same instructional modalities tailored towards individual children's learning needs. Inclusive Education can promote equitable education of all children without discrimination under the same instructional environment which can help them to be self-reliant and have equal opportunities of getting employment.

National policy on education (2013 revised edition) pointed out, the core purpose of education as an enabling instrument that equips the beneficiary with the appropriate knowledge and skills needed to get him or her started in the journey of self-sustenance of the society. The philosophical and moral basis of inclusive Education has it that the child of such an enabling environment would become self-reliant and independent as a productive citizen. This is a fundamental obligation that such education must be available and accessible to all and made compulsory for all children of the same age irrespective of perceived ability.

2.2 Combating Security Issues

Insecurity is a pervasive issue that is deeply affecting the foundations of our nation. Ismaila and Ogbu (2019) define insecurity as a state characterised by fear, anxiety, lack of protection, and inadequate freedom from danger. It reflects a condition where one's life is not safe due to various threats and negative factors. Presently, Nigeria is facing a severe insecurity, crisis, and the patterns of insecurity seem to be regionalized. In the southern region, militia groups are causing disturbances, while kidnapping rates are alarmingly high in the East and South and ritual killings are prevalent in both the East and West. The Northern region is plagued by insurgency, and assassinations occur throughout the entire country. Considering the overall situation in Nigeria, it is evident that the country can no longer considered safe. Many individuals embark on journeys but fail to reach their destinations not due to accidents or natural causes, but because they fall victim to kidnapping.

Okobia (2020) opined that one of the significant security issues plaguing the North Eastern region of Nigeria, with detrimental effects on the Nigerian economy, is the presence of the Boko Haram insurgency. The term "Boko Haram" originated from the Hausa "Boko" meaning "animist*and the Arabic word "Haram" which translates to "sin" or

"forbidden" Onifade, Imhonopi & Urim, (2013). Boko Haram is a highly contentious militant Islamist group in Nigeria that aims to establish Sharia law in the Northern States of the country. The group not only opposes Western Education but also rejects Western culture and modern science. The activities carried out by Boko Haram pose significant security challenges to the contemporary Nigerian State. Investors have expressed concerns about the safety of their Investment in Nigeria due to the actions of this group. These activities include the killing of innocent Nigerians, the rape of women, and the bombing of major cities and police stations primarily in the Northern regions of Borno, Kano, Bauchi, Niger, Yobe, Adamawa and Abuja among others.

Given the above information, in the Northeast region where the issues of Boko Haram are prevalent, it is noticeable that many of the adult militants did not receive any formal education. Therefore, to combat the issues of insecurity in the North East of Nigeria the roles of Mathematics teachers in inclusive Education as stated by the researcher can never be neglected.

2.3 The Role of Mathematics Teachers in an Inclusive Education for Combating Security Issues in Nigeria

The role of Mathematics teachers in an inclusive Education cannot be over-emphasized. A Mathematics Teacher is an individual who exhibits the ability to handle students with special needs and non-disabled or without disability Tali & Paul, (2013). A Mathematics Teacher in an inclusive classroom environment is a leader who can inspire and influence students to learn mathematics despite their physical challenges. Tali and Paul (2014) stressed that students in inclusive Education have equal chances of development which can lead to the development of potential for productive employment with the needed tools for combating security issues. Therefore teachers of Mathematics with their development skills can impact mathematics knowledge to both the disabled and non-disabled students in the same classroom environment to be self-reliant and transformed into productive individuals since mathematics is the bedrock of all civilization. There is a great need for mathematics teachers to create and sustain children's interest in inclusive mathematics also to enhance their future potential for the desired change to be achieved; this can be done by applying several activities as asserted by Kurumeh and Chiasson (2011). Thus

1.   Encouraging critical thinking in children of inclusive Educational school.

Critical thinking is the process which we use when we come up with new ideas. Kurumeh (2006) observed that Mathematics teachers should be able to create critical thinking habits in all the children in an inclusive environment. Hence critical thinking implies correct thinking in the pursuit of relevant and reliable knowledge about the world.

2.   Inculcating learning through participation in groups.

Panya & Adiri (2013) stress that one influential aspect of a Mathematics teacher in an inclusive Education is learning research that focuses on the social basis for all children's learning, inspired by the research of the Russian psychologist, Vygotsky, Vygotsky (1997) as cited in Panya and Adiri (2013) disclose that social contexts (collaborative) allow students to successfully carry out more complex skills than they could execute alone. The role of Mathematics teachers in this aspect is to allow students to perform tasks with one another to provide opportunities not only to imitate what orders are doing but also to discuss the visible task.

3.   Incorporating problem-solving techniques in teaching and learning mathematics.

In the teaching and learning process, Mathematics teachers should involve students in identifying and choosing mathematics problems which grow out of the experiences of both non-disabled and disabled individual students and guide them in getting the solution Eze (2009). The researcher stresses that it follows the steps of the scientific method as well as those of reflective thinking. The teacher should ensure that critical consideration is in the development of skills in analyzing, synthesizing and evaluating for world problem-solving. The aim of incorporating problem-solving techniques is to inculcate in students a true habit of seeking logical answers or finding adequate means of solving problems.

4.   Inculcating creativity in students.

The teacher has to be creative to enable the child to be inventive and imaginative. Creative thinking is the process which we use when we come up with new ideas Kurumeh & Chianson (2011). Creativity is the bringing into being of something which does not exist before, either as a product, a process or a thought. Inculcating the habits of inventiveness and creativity in an inclusive Education programme is highly essential when it comes to mathematics, science and technology.

5.   Inculcating the habits of tolerance in Inclusive Education schools.

The increase in awareness of the benefits of inclusive Education through the integration of students and representative of community members with disabled students could solve a greater role of the teacher in an inclusive school Obani (2006). The Mathematics Teacher should exhibit the habit of tolerance by inviting members of the community of existing disabled students to discuss disability issues with non-disabled members which can enhance good relationships in an inclusive Education programme.

Conclusion

The paper examines the role of Mathematics Teachers in Inclusive Education: Implication for combating security issues in Nigeria. To ensure the desired development changes in every aspect of the socio-economic, and political terrain and good security in the nation the role of Mathematics teachers in an inclusive Education can never be neglected. Such roles of Mathematics teachers in inclusive Education amongst others include: Encouraging critical thinking in students in respective of their physical disability and Inculcating creativity in students.

Recommendation

1. Mathematics teachers should prepare students to identify and analyse the applications of Mathematics in addressing social problems including the problems of insecurity in the country.
2. Serving Mathematics teachers should be made to update themselves through in-service training, workshops, seminars and conferences to equip them with modern strategies for inclusive Education programmes.
3. Government and non-governmental organizations and NGOs that design and plan inclusive Education programmes and services should make the recruitment of quality mathematics teachers a priority along with adequate incentives and job security to motivate them in discharging their duties.
4. To effectively combat future security challenges, the government should engage the community and raise awareness about the role of Mathematics teachers in inclusive Education in combating security challenges.

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CORPORATE GOVERNANCE DISCLOSURE AND STOCK PRICE AMONG LISTED CONSUMER GOODS FIRMS IN NIGERIA

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ABSTRACT

This research investigated the impact of corporate governance disclosure on stock price reaction of consumer goods firms listed on the Nigeria Stock Exchange (NSE). The study involved 16 consumer goods firms listed on the NSE. Secondary data for the study was collected from the annual reports of the sample companies, for the period 2014 to 2022. The panel data regression analysis, particularly the feasible generalized least square regression (FGLS) method was used because it has an inbuilt mechanism to control for the existence of heteroskedasticity and accommodate non-normally distribution, which was discovered in the data. Data analysis revealed that the rate of corporate governance disclosure influences the stock prices of firms, even though profitability, leverage, firm size, and industry did not have any moderating effect on this relationship. These findings show that corporate governance disclosure is a very relevant factor in the decision making of investors in consumer goods firms, which makes it essential for these firms to build trust and display transparency by always disclosing their corporate governance practices in their annual reports, their websites, and other channels.

Keywords: Governance disclosure; profitability; stock price reaction; Consumer Goods

1. Study Background

Corporate governance refers to a set of rules, regulations and mechanisms put in place by a company to provide monitoring and oversight functions on management (Sawicki, 2009). It has been defined by the OECD to be "…the procedures and processes according to which an organisation is directed and controlled. The corporate governance structure specifies the distribution of rights and responsibilities among the different participants in the organisation – such as the board, managers, shareholders and other stakeholders – and lays down the rules and procedures for decision-making." (James, 2023, p. 1). The role of a good corporate governance system is to provide strategic direction of a firm, ensure overall compliance with corporate regulations, and protect stakeholders' interest. The board of directors define the firm's strategy towards corporate social responsibility, tax, wages, and corruption, among other things.

Clark et al. (2014) notes that "good corporate governance strategies can lead to more transparency which ultimately results in lowering the cost of equity, risk, and information asymmetries". Due to its perceived impact on shareholders' wealth, the market reacts to firms' corporate governance mechanisms. Empirical evidence suggests that companies with poor corporate governance structures experience poor operational performance and lower valuation (Clark et al., 2014; Dewi & Handayani, 2017). Three factors are commonly used to measure governance disclosure. These factors include corporate strategy, management, and shareholders. These factors generally deal with issues relating to company's commitments towards adopting global best practices, equality in dealing with shareholders, and employing anti-takeover devices respectively (Pulino et al., 2022).

Conflicting findings are prevalent in the empirical evidence concerning the connection between governance disclosure and stock price reaction. For example, while the results of some studies (like Li et al., 2017; Aboud & Diab, 2018; Rossi & Harjoto, 2020; Xu et al., 2020; Arif et al., 2022; Widiatmoko et al., 2020) indicate a positive correlation between the extent of ESG disclosure and firm value, others like Fatemi et al. (2017) and Cordazzo et al. (2020). For example, Fatemi et al.'s (2017) investigation of 403 companies listed in the United States between 2006 and 2011 demonstrated that even though ESG strengths had a positive impact on the value of firms and their weaknesses were associated with a negative effect, the act of disclosing ESG information itself resulted in a decrease in firm valuation. Yoon, Lee and Byun (2018) however added a caveat to these findings. In their study of the relationship between ESG performance and firm value

using data from companies listed on the Korean Stock Exchange, they found that the effect of CSR practices on the share prices of firms depended on firm characteristics and environmental sensitivity. This is reinforced by Miralles-Quiros et al.'s (2018), whose study of 51 commercial banks from 20 stock exchanges, showed that the significance of ESG performance in relation to value was notably higher for banks situated in countries with a legal system based on common law, particularly in the aftermath of the global financial crisis.

Various studies have also considered the moderating role of other variables like organisational performance, firm size, leverage, etc. One such study in this regard is that by Shakil (2020), which explored the moderating role of firm size in the relationship between ESG disclosure and organisational performance. The results indicated that ESG performance unfavorably affected stock volatility, with firm size playing a significant role in moderating this association. Similarly, Pulino et al. (2022) looked into how organisational performance moderates the relationship between ESG practices and firm price, and found that there was a positive effect of disclosing information related to ESG on financial performance.

Overall, the literature reveals mixed findings on the relationship between governance disclosure and stock price reaction, among other corporate outcomes, underscoring the importance of context, disclosure types, and firm characteristics. Further research is needed to clarify these complex interactions and provide a more comprehensive understanding of the role of governance disclosure in corporate performance.

2.   Theoretical Framework

To help us understand how corporate governance impacts on stock price reaction, this study relies on the stewardship theory, the agency theory and the efficient market hypothesis. The stewardship theory is built on the assumptions concerning human nature; as in, whether or not humans can be trusted to act responsibly, be honest and have integrity. According to the stewardship theory, the fiduciary relationship desired by the shareholders implies that this is the case (Chrisman, 2019; Cater et al., 2019; Till & Yount, 2019; Pacheco, 2019). In essence, the stewardship theory holds the view that shareholders believe that the management is trustworthy enough to act in their best interest (Juanamasta et al., 2019).

Interestingly though, Jensen and Meckling (1976) agency theory holds a different view, that the firm's management, which is supposed to act as an agent for shareholders, rather acted in his own interests and not the interest of the shareholders as assumed by the stewardship theory. According to the agency theory, the management cannot be trusted to act in the public, or shareholders', best interest. And this essentially means that the management cannot be trusted to maximize shareholder value, which is the job they have been tasked to do (Gazali et al., 2020; Rusdiyanto & Narsa, 2019).

A third theory for this study is the efficient market hypothesis (EMH). As Aktan et al. (2018) have pointed out, investors are always on the lookout for ways to increase their gains, and for this reason have one common issue with regard to stock markets, which is the degree of efficiency of these markets. A stock market's informational efficiency is a reflection of the extent to which its financial assets prices adapt to incoming information. The more informationally efficient a market is, the more quickly it reflects incoming information (Lim & Brooks, 2009). The EMH is the theory behind information efficiency. One of its presuppositions is that stock prices adjust to their fair market value in reaction to new information by either increasing or decreasing, thereby making stock price movements random, in what has been referred to as the "Random Walk Hypothesis" (RWH) (Bodie et al., 2003; Aktan et al., 2018).

The EMH and the RWH are closely related as both promote the idea that prices immediately capture new information (Malkiel, 2003), as in react to new information. What this therefore loosely implies is that it will not be beneficial for the investor to analyse a company's financial information, or study past stock prices.

3.   Research method

The study adopted a longitudinal research design to establish the impact of corporate governance disclosure on the stock prices of listed consumer goods firms in the Nigeria Stock Exchange (NSE) for the period 2014-2021. All the 28 consumer goods firms listed on the NSE in December 2021 make up the population of the study, but only 16 of these firms whose reports show corporate governance disclosures during the period of study have been taken as sample for the study (see appendix 1). These 16 firms have produced a combined 144 firm-year observations.

The study used secondary data. While the data on corporate governance disclosure was collected from the Bloomberg database, the annual and financial reports of the firms provided the data for all other variables of the study, except the stock prices of firms that were collected from the NSE website.

The major independent variable of the study is corporate governance disclosure (CGD), while the dependent variable is the stock price reaction (SPR), and firm size (FS) measured by total assets of the firm (Rita et al., 2013), leverage (L) measured by dividing the total firm assets by the total debt (Ambarwati & Dawa, 2022), and profitability (ROA) measured by dividing the net profit with the total assets, are the control variables. Dividend policy (DP) is a dummy variable, which equals to 1 if the firm gives dividend to its shareholders, and 0 if the firm does not.

The study developed two regression equations to test the impact of corporate governance disclosure on stock price reaction. In the first equation, the dependent variable is the corporate governance disclosure score, with the main explanatory variable being profitability (ROA). Other variables like the firm size, leverage, dividend policy, industry and year dummies have been controlled for.

$$Corporate\ governance\ score_{it} = \beta_0 + \beta_1 Profitability_{it} + \beta_2 Size_{it} + \beta_3 Leverage_{it} + \beta_4 Dividend\ policy_{it} + \sum_{j=1}^{j=10} \beta_5 IND_{jit} + \sum_{j=2014}^{j=2022} \beta_6 year_{jit} + \varepsilon_{it} \qquad (1)$$

To test for the impact of corporate governance disclosure on stock price reaction, the model presented in equation (2) is adapted as has been implemented in the work of Barth et al. (1998). The specific form of the model is as follows:

$$SP_{it} = \beta_0 + \beta_1 Corporate\ Governance\ disclosure_{it} + \beta_2 ROA_{it} + \beta_3 Size_{it} + \beta_4 Leverage_{it} + \beta_5 Dividend\ policy_{it} + \sum_{j=1}^{j=10} \beta_6 IND_{jit} + \varepsilon_{it} \qquad (2)$$

The Pearson correlation and the multiple linear regression analyses was used. All statistical analyses were carried out using the STATA 14.2 analysis software. The empirical model

4. Results and Discussion
a. Descriptive Statistics

Table 1 presents the descriptive statistics for the major variables. The table shows that the mean value of the corporate governance disclosure score is 61.757, while ROA averages approximately 4.792. For the control variables, the mean of firm size is 17.840 with an SD of 1.985, while leverage is 57.826% with an SD of 16.318. The dependent variable, stock price, has a mean value of ₦98.986 and a standard deviation of 311.356.

Table 1: Descriptive Statistics

Variable	Obs	Minimum	Maximum	Mean	Std. Deviation
Cgd	144	13	100	61.757	19.757
Fsize	144	14	25	17.840	1.895
Roa	144	-16	31	4.792	7.331
Dp	144	0	1	0.479	0.501
Levr	144	19	98	57.826	16.318
Sp	144	0	1557	98.986	311.356

Table 2 presents the results of the pairwise correlation of the variables. The table has also shown an insignificant association between CGD score and stock prices (coefficient = 0.1308), and there is insignificant relationship with the return on assets (coefficient = -0.0018). Overall, the table has shown that the problem of multicollinearity between the variables does not exist given that the correlation coefficients between the predictor variables have not exceeded 80%.

Table 2: Pairwise correlation matrix

	cgd	Fsize	roa	Sp	levr

Cgd	1.000			
Fsize	-0.1018	1.000		
Roa	0.0018	0.0842	1.000	
Sp	0.1308	0.2100	0.4796	1.000	
Levr	0.1349	0.1952	0.0535	0.3267	1.000

b. Diagnostic tests

The study has undertaken various diagnostic tests to ensure the validity of the study outcomes. Among these are the Shapiro-Wilk test, the test for heteroskedasticity using the Bruesch-Pagan test, and the test serial correlation using the Wooldridge test. The results of these tests are presented on Table 3 to 5.

The Shapiro-Wilk test for normality is presented on Table 3. From the results of the test, it is clear that, except leverage, every other is not normally distributed since they all have significant p-values (Prob>z). As such, we reject the null hypothesis of normal distribution.

Table 3: Shapiro-Wilk Test for Normality

Variable	Obs	W	V	Z	Prob>z
Cgd	144	0.96204	4.265	3.281	0.00052
Roa	144	0.95646	4.892	3.592	0.00016
Fsize	144	0.96152	4.323	3.312	0.00046
Levr	144	0.98924	1.209	0.429	0.33387
Sp	144	0.32113	76.278	9.805	0.00000

Table 4 presents the results of the test for multicollinearity using the Variation Inflation Factor (VIF) test. It is seen in the table that stock price has the highest VIF of 1.54, while firm size has the lowest VIF of 1.14. The mean VIF value is 1.29. Since all of the expository variables did not possess a VIF value close to the threshold of 10, it is concluded that these variables do not have any concern of multicollinearity, meaning that we have not put in too many variables that measure corporate governance disclosure.

Table 4: Variance Inflation Factor

	VIF	1/VIF
sp	1.54	0.651399
roa	1.37	0.729654
dp	1.22	0.819834
levr	1.17	0.855883
Fsize	1.14	0.874023
Mean VIF	1.29	

Table 5 shows the results of the test for autocorrelation and heteroskedasticity. Using the Wooldridge test, the table shows that with an F value of 33.34 and a p-value of 0.0000, the null hypothesis of no autocorrelation is accepted. Also, the Breusch-Pagan/Cook-Weisberg test shows that with a p-value of 0.0475, we reject the null hypothesis that there is constant variance among the residuals and conclude heteroscedasticity is present in the data.

Table 5: Model regression diagnostic tests

Test	Test type	F value	p-value	Conclusion
Autocorrelation	Wooldridge test	33.34	0.0000	No serial correlation
Heteroskedasticity	Breusch-Pagan/ Cook-Weisberg	3.93	0.0475	Presence of heteroscedasticity

c. Panel Regression

Since the diagnostic tests carried out on the data showed that there is the presence of heteroscedasticity and non-normality of variables, the feasible generalized least square regression (FGLS) method of analysis is preferred for analyzing the data. This is because the FGLS method possesses in-built mechanisms for accommodating non-normality and controlling for the existence of heteroskedasticity (Baltagi, 2010). Table 6 presents the results of the FGLS test for the first model of the study, which seeks to ascertain how profitability impacts on corporate governance disclosure scores.

Table 6: Estimated Panel Feasible Generalised Least Square (FGLS) Regression
(Dependent = ROA)

ROA	Coef.	Std. Err.	z	P>|z|	[95% conf. interval]	
cgd	-0.0104218	0.0254383	-0.41	0.682	-0.06028	0.0394363
fsize	-0.0134608	0.2875598	-0.05	0.963	-0.5770677	0.5501461
sp	0.0114561	0.0019624	5.84	0.000	0.0076099	0.0153024
levr	-0.0550302	0.0324918	-1.69	0.090	-0.1187131	0.0086526
dp	1.862105	1.106644	1.68	0.092	-0.3068778	4.031087
Ind	-0.0296881	0.3305592	-0.09	0.928	-0.6775723	0.6181961
Constant	6.921864	5.549011	1.25	0.212	-3.953998	17.79773
mean dep var	4.791667	SD dep. Var		7.331201		
Num. of obs	143	Chi-square		54.27		
Prob> chi^2	0.0000	Akaike Crit (AIC)				

With a p-value of 0.682 which is non-significant at all conventional levels, Table 6 shows that the profitability of the firm has no significant impact on its corporate governance disclosure score. In fact, the profitability of the firm only impacts on the stock price of the firm. This gives a clear indication consumer goods firms listed in the NSE with higher profitability did not necessarily have higher corporate governance disclosures during the period that this study covered, even though it did impact on their stock prices.

With regard to the control variables in the equation, the results presented on Table 6 show that the result of non-significance of the impact of profitability on corporate governance disclosure was true for all firms regardless of their industry (coef. = -0.0296881; p-value = 0.928), the size of the firm (coeff. = -0.0134608; p-value = 0.963), whether or not they had a dividend policy (coeff. = 1.862105; p-value = 0.092), or leverage (coeff. = -0.0550302; p-value = 0.090).

Table 7 presents the results for testing of the second equation to assess the impact of corporate governance disclosure on stock prices of consumer goods firms on the NSE.

Table 7: Estimated Panel Feasible Generalised Least Square (FGLS) Regression

(Dependent = CGD)

CGD	Coef.	Std. Err.	z	P>|z|	[95% conf. interval]	
sp	0.0138319	0.0062745	2.20	0.027	0.0015342	0.0261297
roa	-0.0182466	0.2467888	-0.07	0.941	-0.5019439	0.4654506
fsize	-1.263167	0.9984437	-1.27	0.206	-3.220081	0.6937462
levr	0.1348616	0.1053703	1.28	0.201	-0.0716603	0.3413835
dp	-10.17871	3.466938	-2.94	0.003	-16.97378	-3.383636
ind	-0.8151205	1.119885	-0.73	0.467	-3.010054	1.379813
Constant	83.33616	18.63184	4.47	0.000	46.81842	119.8539
mean dep var	61.75694	SD dep. var		19.89316		
Num. of obs	143	Chi-square		18.52		
Prob> chi²	0.0051	Akaike Crit. (AIC)				

Table 7 shows the results for the impact of corporate governance disclosure on stock prices among other control variables. The table shows that corporate governance disclosure impacts on the stock prices of consumer goods firms listed on the NSE at the 0.05 level of significance (coeff. = 0.0138319; p-value = 0.027). This means that the hypothesis that firms with more positive corporate governance reports will have their stock prices impacted positively is accepted.

Of the control variables, only dividend policy (coeff. = -10.17871; p-value = 0.003) is significantly impacted by the corporate governance disclosure score. All other variables, including the profitability (ROA) (coeff. = -0.0182466; p-value = 0.941), firm size (coeff. = -1.263167; p-value = 0.206), leverage (coeff. = 0.1348616; p-value = 0.201), and industry (coeff. = -0.8151205; p-value = 0.467) do not have any significant influence on the relationship between corporate governance disclosure and stock prices of consumer goods firms listed on the NSE.

5.   Summary and Conclusion

This study investigated the influence of profitability on the corporate governance disclosure of consumer goods firms listed in the Nigeria Stock Exchange, and also how the stock prices of these firms reacted to their corporate governance disclosure, using data collected from 2014 to 2021. The scores for corporate governance disclosure were collected from the Bloomberg database. Because of the presence of heteroskedasticity in the data, the feasible generalized least square (FGLS) regression method with a heteroskedastic but uncorrelated, and an independent form of autocorrelation was used to analyse the data. As Baltagi (2010) had explained, this method is very useful because it possesses the mechanism to accommodate non-normality and control for heteroskedasticity.

Following the regression analysis, it was discovered that the profitability of the firm has no significant impact on its corporate governance disclosure, but only impacts on the stock price of the firm, regardless of firm industry, size, leverage, or dividend policy. However, the study found that there was a significant and mildly positive impact of corporate governance disclosure on the stock prices of consumer goods firms in the NSE. Of the control variables, only

the dividend policy of the firm significantly influenced this relationship. Looking at this finding from the perspective of the agency theory, it indicates that shareholders react positively to the practice of reporting their governance practices by the management. This is because, as it is the presupposition of the theory, firm management cannot be trusted to act in the interest of the shareholders. Therefore, such governance disclosures and reports are necessary as one of the tools for monitoring the 'self-serving agents'. Other tools as highlighted by James (2023) include the implementation of effective corporate governance and control structures. Another way of explaining this finding is through the efficient market hypothesis. Because investors are always looking out for how to increase their gains, an efficient market, which implies that information is efficiently flowing into the market especially through disclosures and reports, will make the stock prices of firms adjust to their fair market value in reaction to new information (Aktan et al., 2018; Bodie et al., 2003).

Beyond satisfying the assumptions of the theories of this study, the findings agree with those of previous other findings, like Li et al. (2017), Aboud and Diab (2018), Rossi and Harjoto (2020), Xu et al. (2020), Arif et al. (2022), and Widiatmoko et al., (2020), all of whom found similar results of a correlation between ESG disclosure and stock prices of firms across various industries, while disagreeing with studies that did not find any positive correlation between corporate governance disclosure and stock price reaction, like Fatemi et al. (2017), and Cordazzo et al. (2020). Also, unlike in Yoon et al.'s (2018), Miralles-Quiros et al.'s (2018), Shakil's (2020) and Pulino et al.'s (2022) studies, the present study did not find any influence of firm characteristics on the relationship between corporate governance disclosure and stock price reaction.

This work contributed to the growing literature on the impact of corporate governance disclosure on stock price reaction by filling the gap that is created by the non-existence of studies with the characteristics of the present study, like using consumer goods firms listed in the NSE for the period of 2014-2021, and adopting the FGLS method of analysis. It is however suggested that future studies investigate a similar topic but with a larger sample size, and across countries to determine whether the findings can be similar in different countries, which will indicate if truly the industry has had a significant impact in the present study.

The results from the study further expands the current understanding on the issue of corporate governance disclosure and stock prices in Nigeria as an emerging market, thereby providing a different perspective to the debate and contributing to the literature. Besides its theoretical significance, the study has practical implications for managers. One key implication is that managements of consumer goods firms in Nigeria are beginning to be more aware of how important it is to disclose their activities considering the need for transparency and building trust with shareholders, and that shareholders value such disclosures which is why the stock prices react either positively or negatively to such reports or disclosures. This calls for the provision of a legal backing to the corporate governance disclosure of firms in order to build investors' and other stakeholders' confidence in these activities.

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APPENDIX

Table 1: Sampled Firms and their Industries

Industry	Firms
Alcoholic beverage	International Breweries Plc.
	Guinness Nig. Plc.
	Champion Breweries
	Nigerian Breweries
Conglomerate	Dangote
	Honeywell
Food and agro-allied	Nascon Allied Int. Plc.
	McNichols Consolidated
	Nestle Nig. Plc.
	N N Flour Mills. Plc
	Flour mills
	Multi-Trex Integrated
Confectionary	Cadbury
Consumer goods	Vitafoam
	PZ
	Nigerian Enamelware Plc.3

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EXPLORING THE SOCIO-ECONOMIC IMPACT OF HERBAL MEDICINE PRACTICES IN ONDO STATE, NIGERIA

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ABSTRACT

The study explores the Socio-Economic Impact of Herbal Medicine Practices in Ondo State, Nigeria, with a focus on four key health outcomes: Infant Mortality Rate (IMR), Under-five Mortality Rate (UMR), Maternal Mortality Rate (MMR), and Life Expectancy (LEX). Employing the Grossman Model of Health Demand as the theoretical framework, which conceptualizes health as capital that individuals invest in to enhance their well-being and productivity, the study examines the relationships between Herbal medicine practices and these health outcomes. Data were collected through a structured questionnaire administered to a sample of 400 respondents, drawn from a population of 5,316,600. The study utilized the logistic regression model and SPSS version 23 to analyze the data. The study also adopts the purposive/judgmental sampling technique, using Taro Yamane (1967) to determine the sample size. The findings reveal a nuanced relationship between Herbal medicine and health outcomes: while Herbal medicine is associated with a positive increase in life expectancy, it is inversely related to infant mortality, under-five mortality, and maternal mortality rates. The results underscore the importance of integrating Herbal medicine into modern healthcare systems to leverage its benefits in improving health outcomes and fostering socioeconomic development. The study advocates for policies that support research on Herbal medicine, enhance healthcare provider training, and establish regulatory standards to ensure the efficacy and safety of Herbal practices. By adopting these measures, societies can optimize health investments, reduce healthcare costs, and stimulate economic productivity, ultimately contributing to comprehensive socioeconomic growth.
Keyword: Herbal Medicine, Infant Mortality, Under-five Mortality, and Maternal Mortality

1 INTRODUCTION

The art of healing comes from nature, not from the physician. Therefore, the physician must start from nature, with an open mind." - Paracelsus_

Paracelsus's words capture the essence of Herbal medicine, which is deeply rooted in natural healing practices that have been cultivated over millennia. Herbal medicine encompasses a variety of approaches, including herbal remedies, acupuncture, and spiritual healing, all of which are integral to the cultural and historical contexts of different societies (World Health Organization [WHO], 2019).

As the world continues to advance technologically and medically, there is a growing recognition of the need to integrate these ancient practices with modern healthcare systems to enhance health outcomes, improve life expectancy, and contribute to socio-economic development

The global healthcare landscape is a rich tapestry woven from diverse medical traditions and practices. Among these, Herbal medicine holds a prominent place, offering a unique perspective on health and wellness that has been cultivated over millennia. Herbal medicine encompasses a variety of practices, including herbal remedies, acupuncture, and

spiritual healing, deeply rooted in the cultural and historical contexts of various societies (World Health Organization [WHO], 2019). As the world continues to advance technologically and medically, there is a growing recognition of the need to integrate these age-old practices with modern healthcare systems to enhance health outcomes, potentially improve life expectancy, and contribute to socio-economic development.

Herbal medicine, defined by the WHO as "the sum total of the knowledge, skills, and practices based on the theories, beliefs, and experiences indigenous to different cultures," plays a crucial role in primary healthcare for many communities, especially in developing countries (WHO, 2019). For instance, in China, Herbal Chinese Medicine (TCM) is not only a complementary healthcare option but also an integral part of the national healthcare system, contributing to the management of chronic diseases and the promotion of preventive healthcare strategies (Zhou et al., 2020). This integration not only supports individual health but also has broader socio-economic benefits, such as reducing healthcare costs and increasing workforce productivity.

The socio-economic implications of Herbal medicine are profound. In many low- and middle-income countries, where access to modern healthcare facilities may be limited, Herbal medicine serves as a critical resource for the population. It offers cost-effective treatment options that are culturally accepted and widely available. By providing affordable healthcare solutions, Herbal medicine can alleviate the economic burden on families and communities, reduce absenteeism due to illness, and enhance overall economic productivity (Frass et al., 2012).

Globally, Herbal medicine is a vital component of healthcare systems, especially in regions where modern medical infrastructure is limited. According to the World Health Organization (2019), over 80% of the population in developing countries relies on Herbal medicine as a primary source of healthcare. This widespread reliance emphasizes the crucial role Herbal medicine plays in filling gaps left by conventional medical systems and providing culturally relevant treatment options.

In the broader African context, Herbal medicine is integral to the healthcare landscape. In sub-Saharan Africa, it offers cost-effective and accessible health solutions, particularly in areas where conventional medical services are scarce (Bodeker et al., 2014). The African Union (2021) highlights the importance of integrating Herbal medicine with modern healthcare practices to improve health outcomes and address healthcare disparities effectively. Similarly, in Nigeria, Herbal medicine is not only widely practiced but also holds significant cultural value. The National Institute for Pharmaceutical Research and Development (NIPRD, 2020) reports that approximately 70% of Nigerians use Herbal medicine either alongside or as an alternative to conventional treatments. This widespread use underscores the importance of Herbal medicine in Nigeria's healthcare system, reflecting its role in meeting the diverse health needs of the population.

In Ondo State specifically, Herbal medicine remains a crucial healthcare resource. Approximately 60% of the population relies on Herbal healers for various health issues, indicating a strong, culturally ingrained trust in these practices (Eze & Ijeoma, 2019). Despite the availability of modern medical facilities, Herbal medicine continues to serve as a primary healthcare source, particularly in rural areas where access to conventional services is limited. Herbal medicine has long been a cornerstone of healthcare, deeply ingrained in the region's cultural and historical fabric.

Historical records and contemporary studies reveal that indigenous healing practices, including herbal remedies and spiritual treatments, have been employed for centuries to address various health conditions (Nnaji & Osuagwu, 2018). This longstanding tradition highlights the significant role of Herbal medicine in Ondo State's healthcare landscape, where it continues to be a primary resource for many.

Integrating Herbal medicine with modern healthcare systems in Ondo State presents a significant opportunity to enhance health outcomes and promote socioeconomic development. By acknowledging the historical and cultural significance of Herbal practices while addressing contemporary health challenges, Ondo State can leverage these practices to improve overall health and economic well-being. This integration aligns with global and regional trends advocating for a blended approach to Herbal and modern medicine, aiming to create a more inclusive and effective healthcare system.

The confluence of Herbal wisdom and modern medical advancements offers a promising path toward a more comprehensive healthcare approach. Embracing the holistic and culturally resonant aspects of Herbal medicine while addressing its challenges through scientific validation and integration with modern practices can lead to improved health outcomes and socioeconomic benefits, reinforcing the profound connection between nature, health, and human well-being in Ondo state. Just as Buddha's wisdom that "Health is the greatest gift, contentment the greatest wealth, faithfulness the best relationship" underscores the profound connection between health and overall well-being, emphasizing that true health and contentment stem from both natural and culturally attuned practices. It is in this light that this study seeks to Explore the Socio-Economic Impact of Herbal Medicine Practices in Ondo State, Nigeria. The objectives of the study are therefore: (1) Evaluate the effect of Herbal Medicine on Infant Mortality Rate in Ondo state

Nigeria. (2) Examine the effect of Herbal Medicine on Under-five Mortality Rates in Ondo state Nigeria. (3) Examine the effect of Herbal Medicine on Maternal Mortality Rate in Ondo state Nigeria. (4) Evaluate the effect of Herbal Medicine on Life Expectancy in Ondo state Nigeria. The rest of the study is presented as follows: section 2 presents the literature review involving the theoretical underpinning of the study and the review of empirical studies. Section 3 focuses on material and methods which captures the data and model specifications. Section 4 analyses the data and divulges the findings, while sections 5 conclude the paper and highlights the recommendations.

2.0   REVIEW OF RELATED LITERATURE
2.1   Conceptual Framework
2.1.1   Herbal Medicine

Herbal medicine, also known as botanical medicine, refers to the use of plants or plant parts to treat health conditions and promote wellness. These treatments can include leaves, bark, berries, flowers, and roots and are often used in various forms such as teas, extracts, tablets, or capsules. (National Center for Complementary and Integrative Health [NCCIH], 2021). Herbal medicine is the practice of using herbs and herbal preparations to maintain health, prevent illness, or treat disease. This form of medicine is based on traditional knowledge and empirical evidence gathered over centuries, often integrating cultural beliefs and practices." (World Health Organization [WHO], 2019). Herbal medicine is the use of plant-based substances to treat illnesses and promote health. These substances include a variety of herbs, herbal materials, herbal preparations, and finished herbal products that contain active ingredients derived from parts of plants, or other plant materials. Tyler, Brady, & Robbers (1988). Herbal medicine involves the therapeutic use of plants and plant extracts to address various health conditions. It relies on the traditional knowledge of medicinal plants to support, heal, and maintain health. Barnes, Anderson, & Phillipson (2007).

2.1.2   Socio-Economic Development

United Nations Department of Economic and Social Affairs. UNDESA (2021) defined Socioeconomic development as the progressive reinforcement of a socioeconomic organization's quantitative and qualitative dimensions towards a higher level of efficiency, well-being, justice, and democracy at all levels, which incorporates public concerns in developing social policy and economic initiatives.

The ultimate objective of social development is to bring about sustained improvement in the well-being of the individual, groups, family, community, and society at large

World Bank (2019). Noted that socioeconomic development, is an economy that Sustained increase in the economic standard of living of the country's population, normally accomplished by increasing its stocks of physical and human capital and thus improving its technology, by processing the well-being and quality of life of the nation, region, local community, or by improving individuals according to targeted goals and objectives.

2.1.3   Health
Health is a state of complete physical, mental and social well-being and not merely the absence of disease and infirmity, which is promoted by encouraging healthful activities, such as regular physical exercise and adequate sleep, and by reducing or avoiding unhealthful activities or situations, such as smoking or excessive stress (WHO, 2016). However, the definition of health adopted by providers and government has implication for the process, measurement and range of services offered. In 2018 WHO defined health as a state of complete physical, social and mental well-being and not merely absence of disease and infirmity". In this way, health is metabolic efficiency while sickness or ill health is metabolic inefficiency. A state of complete physical, mental, and social well-being: not just absence of disease or infirmity is a healthy status- a status in which individuals can lead social and economically productive life.

2.1.4   Health Outcomes

Health outcome simply refers to population health status or condition within a given period of time. It is a change in the health status of an individual, group, or population which is attributable to a planned intervention or series of interventions, regardless of whether such an intervention was intended to change health status (CDC, 2022). Health outcome is usually measured by health status indicators or indices. However, though there seem to be no consensus on how to quantitatively measure health outcome, different scholars on population health have adopted various indices as proxies for measuring health outcome. Some of these indices include self-rated health, infant mortality rate, population

mortality rate, life expectancy, average age at death, child nutritional status, diseases burden and maternal mortality (Orji & Okechukwu, 2015).

2.1.5   Infant Mortality

Infant mortality refers to the death of infants under the age of one year per 1,000 live births in a given population within a specified period. It is a critical indicator of the overall health and well-being of infants in a society, reflecting factors such as healthcare access, maternal health, socioeconomic conditions, and public health interventions (WHO, 2023).

Infant mortality refers to the number of deaths of infants under one year of age per 1,000 live births in a specified geographical area or population within a given time period. It is a critical health indicator influenced by factors such as maternal health, access to healthcare services, socioeconomic conditions, and public health interventions (CDC, 2021).

2.1.6   Under-Five Mortality:

Under-five mortality, also known as child mortality, refers to the probability of dying before reaching the age of five years per 1,000 live births. It serves as a key indicator of child health and well-being, encompassing deaths from infancy through early childhood due to preventable and treatable causes such as malnutrition, infectious diseases, and inadequate healthcare (UNICEF, 2021).

Under-five mortality, also known as child mortality, refers to the probability of dying before reaching the age of five years per 1,000 live births. This measure includes deaths of children under five due to various causes, including infectious diseases, malnutrition, injuries, and inadequate access to healthcare services. It serves as a critical indicator of child health and well-being in populations (WHO, 2023).

2.1.5   Maternal Mortality:

Maternal health refers to the health of women during pregnancy, childbirth and the postpartum period. It refers to deaths related to pregnancy or childbirth. While motherhood is often a positive and fulfilling experience, for too many women it is associated with suffering, ill-health and even death. According to Maternal and Neonatal Programme Effort Index (MNPI, 2010) maternal mortality as the deaths caused by complications due to pregnancy or childbirth, these complications may be experienced during pregnancy, delivery itself, or 42 days following childbirth. For each maternal death, many more suffer injuries, infection and disabilities brought about by pregnancy or childbirth complications. The major direct causes of maternal morbidity and mortality include hemorrhage, infection, high blood pressure, unsafe abortion and obstructed labour.

2.2.   Theoretical framework
2.2.1   The Grossman Model of Health Demand

The study is hinged on The Grossman Model of Health Demand, introduced by Michael Grossman in 1972, offers a robust framework for analyzing the interplay between Herbal medicine, health outcomes, and socioeconomic development. This model views health as a form of capital—similar to physical assets—that depreciates over time but can be preserved or improved through various investments. Herbal medicine, within this framework, is seen as a crucial investment in health capital. Practices such as herbal remedies, dietary adjustments, and culturally specific treatments are employed to reduce health depreciation and enhance overall well-being. Grossman's theory posits that health is valued not only for its inherent benefits but also for its role in improving productivity and quality of life. By investing in Herbal medicine, individuals aim to prevent diseases and prolong their productive years. This is particularly pertinent in regions where Herbal medicine is more accessible and affordable compared to conventional healthcare options. Such investments help maintain health capital, leading to better health outcomes and increased life expectancy. Moreover, the Grossman Model links improvements in health to broader socioeconomic development. When health capital is bolstered through Herbal medicine, it can result in heightened economic productivity and lower healthcare costs. As individuals enjoy better health and longer lives, they are able to contribute more effectively to the economy. This enhanced economic participation supports overall socioeconomic development by fostering a more productive and healthier population.

2.3   Empirical Review

Patel and Sharma (2019), examined Herbal Medicine and Its Effect on socioeconomic development: an in-depth analysis on Life Expectancy: Evidence from Rural India. The study offers a comprehensive examination of how Herbal medicine

influences life expectancy in rural settings. Conducted in India, this research provides valuable insights into the role of Herbal medicine in extending life and improving health outcomes. The study utilized a longitudinal survey design, collecting data from 1,200 households over five years through structured interviews and health assessments. This sample was carefully selected to ensure it represented various geographical and cultural contexts within rural India. By focusing on both users of Herbal medicine and those relying primarily on conventional medical services, the research aimed to capture a broad perspective on the effects of Herbal practices. Key health indicators such as life expectancy, incidence of chronic diseases, and overall health status were assessed. Life expectancy data were obtained from local health records and demographic surveys. Statistical methods, including logistic regression model analysis and survival analysis, were employed to analyze the data and determine the impact of Herbal medicine on life expectancy, while controlling for confounding factors such as socioeconomic status, access to healthcare, and lifestyle. The findings of the study revealed a significant positive correlation between the use of Herbal medicine and improved life expectancy. Herbal medicine practices, which include herbal remedies and preventive health measures, were shown to enhance health outcomes by offering accessible and culturally appropriate health interventions. This research underscores the importance of Herbal medicine in contributing to longer, healthier lives in rural areas, demonstrating its role in both health improvement and socioeconomic development.

3.1   MATERIALS AND METHODS

The study adopted Quantitative research design. Which was used to evaluate the Socio-Economic Impact of Herbal Medicine Practices in Ondo State, Nigeria. The study used the descriptive (survey) research design which was used, given that the research contains two variables viz: Herbal medicine (independent) and socioeconomic development, (dependent variables) The study used Questionnaire, by distribution via resident within the three senatorial zones, of Ondo State. These include Ondo North, Ondo South, and Ondo Central. However, the target population among these senatorial districts are the most populus local government area, who directly or indirectly utilize Herbal medicine, due to it availability and predominancy in the state. The total population of the state, 5,316,600 this was gotten from National Population commission (NPC 2022). The study also adopts the purposive/judgmental sampling technique, using Taro Yamane (1967) to determine the sample size which was five million, three hundred and sixteen thousand and six hundred (5,316,600) from the earmarked population, given a total sample of four hundred (400) for the study.

3.2   Model specification

The study adapts the logistic model proposed by work of Patel and Sharma (2019), who examined Herbal Medicine and Its Effect on socioeconomic development: an in-depth analysis on Life Expectancy: Evidence from Rural India. Since the independent variable (Socioeconomic Development) takes values of either zero (0) or (1), it is assumed that the error term follows a logistic distribution, regression estimates by the logit model. Specifically, the model takes the implicit form as follows:

$$Y = (p/1-p) = \beta o_X + \beta_1 x1_i + \beta_2 x2_i + \beta_3 x3_i + \text{---} + \beta_k x k_i + \varepsilon_t \qquad \text{-} \qquad \text{-} \qquad \text{-} \qquad (3.1)$$

Where $X_1 \text{- - - -} X_k$ were the predictor variables- type of residence (rural or urban), educational

Level of the household head, region, size of household, age of household head, sex of household, head, respectively; and p denoted the probability that a person has been faced with maternal mortality case. Including variables of interest, the first model is specified as:

$$SED = f (EDU, INC, CCH, IMR) \text{-} \qquad \text{-} \qquad \text{-} \qquad \text{-} \qquad \text{-} \qquad (3.2)$$

Where:

EDU = Education;

INC = Income;

PDT = Productivity;

IMR = Infant mortality Rate;

MMR = Maternal Mortality Rate

SED = Socioeconomic Development

For this study, equation 3.2 was modified by replacing its endogenous variables with the current study variables and stating that socio-economic development proxied by Infant mortality Rate (IMR), Under-five Mortality Rates (U_5MR), Maternal Mortality Rate (MMR) and life expectancy (LEX) is a function of Herbal Medicine.

This functional relation was stated as thus:

$$TAM = f(IMR, U_5MR, MMR, LEX) \text{- - - - -- - -- --- - - - - - -- --- -- - - - - -- -- - -} \text{-}(3.5)$$

Where:

HEM = Herbal Medicine

IMR = Infant mortality Rate;

U_5MR = Under-five Mortality Rates

MMR = Maternal Mortality Rate

LEX = Life Expectancy

β_o = Constant
$\beta_1 - \beta_4$ = estimated parameters

ε_t = random disturbance term

Equation 3.5 was stated in stochastic explicitly form as:
$$HEM = \beta_o + \beta_1\,IMR + \beta_2\,U_5MR + \beta_3\,MMR + \beta_4\,LEX + \varepsilon_t \qquad - \qquad -(3.6)$$
The a priori expectation of the parameters to be estimated are as expressed below:
i. ε_t which is the random disturbance term is serially independent assumed to be Constant.
ii. $\beta_1, \beta_2, \beta_3,$ and $\beta_4 < 0$.
This implies that the coefficients of Herbal Medicine are expected to be Negative. Meaning that they have a negative relationship with socioeconomic development. This imply that an increase in HEM will lead to a decrease in (IMR, U_5MR, and MMR). All things been equal.

4.1 Data Analysis and Discussions

it was observed that out of the 400 questionnaires distributed, 11 were not returned, and 22 were not properly filled; thus, making the properly filled questionnaire to be 367, which was returned. The 367 properly filled questionnaires were thus used for the analysis. This shows that 91.7 percent of the administered questionnaire were used for the analysis in this study.

4.1 Model Matrix Estimation Results
Table 4.1: Model Estimation Results

Variable	B	S.E.	Wald	Df	Sig.	Exp(B)
IMR	-35.008	.701	60.899	1	.004	.929
U_5MR	-7.112	.658	39.069	1	.003	.371
MMR	-26.087	.967	46.394	1	.002	.3.21
LEX	33.007	.706	59.798	1	.004	.2.29
Constant	18.348	2.686	56.732	1	.000	76.000
Hosmer-Lemeshow	110					
Nagelkereke R Square	.723					
Cox & Snell R Square	.636					
-2 Log likelihood	21.562					

Source: SPSS Computations (2023)

$$HEM = 18.348 - 35.008\,IMR - 7.112\,U_5MR - 26.087\,MMR + 33.007\,LEX - \qquad -(4.1)$$

Table 4.12 shows the coefficient for IMR (-35.008). is negative. This indicates a negative impact on HEM. for one-unit increase in Herbal Medicine while holding all other variables constant is associated with a decrease of Infant Mortality Rate (IMR) by -35.008. This is in conformity with a prior expectation.

From Table 4.12, it was revealed that the coefficient for U_5MR (-7.112) is negative. This indicates a negative impact on HEM, which is line with a prior expectation. A unit change in Herbal Medicine tends to decrease Under-five Mortality Rates by -7.112.

Table 4.12 shows the coefficient for MMR (-26.087). is negative. This indicates a negative impact on HEM. for one-unit increase in Herbal Medicine while holding all other variables constant is associated with a decrease of Maternal Mortality Rate (MMR) by -26.087. This is in conformity with a prior expectation

Table 4.1 shows the coefficient for LEX (33.007). is positive. This indicates a positive impact on HEM. for one-unit increase in Herbal Medicine while holding all other variables constant is associated with an increase of Life Expectancy ate (LEX) by 33.007. This is in conformity with a prior expectation.

From Table 4.1: The Hosmer-Lemeshow statistic is 0.110 at a critical value of 0.005, this means the calculated test statistic is less than the critical value. Therefore, the findings suggest that there is no evidence to reject the null hypothesis of good fit. In other words, the logistic regression model fits the data adequately at a significance level of 0.005.

The Nagelkerke R Square is 0.723, indicating that the models are explained approximately 84.4% of the variability in Herbal Medicine (HEM). This suggests that Infant Mortality Rate (IMR), Under-five Mortality Rates (U_5MR), Maternal Mortality Rate (MMR) and life expectancy (LEX) are strong predictors of Herbal Medicine.

Similarly, The Cox & Snell R Square is 0.636, which provides a measure of how well the models fits compared to a null model with no predictors. It suggests that the models with Infant Mortality Rate (IMR), Under-five Mortality Rates (U_5MR), Maternal Mortality Rate (MMR) as predictors, significantly impact Herbal Medicine by 62.8%. The -2 Log Likelihood is 21.562, which indicate an excellent fit. Therefore, overall, the evidences suggest that Herbal Medicine is negatively significant predictor of Infant Mortality Rate (IMR), Under-five Mortality Rates (U_5MR), Maternal Mortality Rate (MMR), while Life Expectancy is positive, with the logistic regression model providing valuable insights into how the presences of Herbal Medicine affects Infant mortality Rate (IMR), Under-five Mortality Rates (U_5MR), Maternal Mortality Rate (MMR) and life expectancy (LEX) on socioeconomic development.

4.2.1 Reliability Statistics

Table 4.2: Reliability Statistics Test

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.965	.973	5

Source: SPSS Computations (2023)

Table 4.2. shows the provided reliability test results, which include Cronbach's Alpha values of 0.965 and 0.973 based on standardized items, indicate a very high level of internal consistency in the dataset used for the regression analysis. This suggests that the variables Herbal Medicine Rate (HEM), Infant mortality Rate (IMR), Under-five Mortality Rates (U_5MR), Maternal Mortality Rate (MMR) and life expectancy (LEX) are highly reliable in measuring the intended constructs and are likely to produce consistent and dependable results.

Cronbach's Alpha is a measure of internal consistency reliability, and it assesses how well a set of variables or items in a scale or questionnaire measures a single underlying construct. In this context, the high Cronbach's Alpha values indicate that the variables used in the regression model are internally consistent and that they collectively provide a reliable measure of the relationships between Herbal Medicine (HEM), Infant mortality Rate (IMR), Under-five Mortality Rates (U_5MR), Maternal Mortality Rate (MMR) and life expectancy (LEX).

The high internal consistency revealed by the reliability test results has significant implications for the research's data quality, research validity, and policy relevance. Firstly, it underscores the high quality of the data used in the regression analysis, affirming the reliability of the variables representing Herbal Medicine Rate (HEM), Infant mortality Rate (IMR), Under-five Mortality Rates (U_5MR), Maternal Mortality Rate (MMR) and life expectancy (LEX). This bolstered data quality enhances the overall validity of the regression model's findings, instilling confidence in researchers that the relationships explored are consistent and dependable.

Consequently, policymakers and public health officials can place greater trust in utilizing these findings to inform policy decisions and interventions aimed at utilizing Herbal Medicine and improving socioeconomic development by reducing Infant Mortality Rate (IMR), Under-five Mortality Rates (U_5MR), Maternal Mortality Rate (MMR) and improving life expectancy (LEX) in Ondo State. The reliability of the data is an essential foundation upon which effective public health strategies and resource allocation can be built.

4.3.1 Normality Tests of the Study
Table 4.3.: Normality Test of Variables

	Kolmogorov-Smirnov	Shapiro-Willk

Constructs	Statistic	Df	Sig	Statistic	Df	Sig.
Herbal Medicine (HEM)	0.997	367	0.059	0.991	367	0.057
Infant Mortality. R (IMRR)	0.981	367	0.191	0.993	367	0.207
under 5 Mortality. R (U$_5$MR)	0.984	367	0.211	0.992	367	0.179
Maternal Mortality. R (MMR)	0.979	367	0.124	0.994	367	0.313
Life Expectancy (LEX)	0.954	367	0.016	0.987	367	0.015

Source: Author's Computations 2023 (Microsoft Excel-16)

Table 4.18, show the result of Kolmogorov-Smirnov and Shapiro-Willks test, the statistic values of the data under the study are close to 1 suggesting that the data is normally distributed. All the variables' data showed P-value is greater than 0.05 except life expectancy (LEX) which show $P < 0.05$, its test statistic value was 0.954. Thus, the Kolmogorov-Smirnov and Shapiro-Willks significant range is less than 1 and 3 respectively which is less than 0.05 percent level of significant. Hence, this confirmed that the data were normally distributed.

4.4   Testing of Hypothesis Results

4.4.1   Test of hypothesis One

H01: Herbal Medicine Rate (HEM), has no significant effect on Infant Mortality Rate (IMR) in Ondo State.

The logistic regression results for MAL include a significant p-value (Sig.) of 0.002, and the coefficient for IMR is -35.008. Based on these results, we accept the alternative hypothesis for IMR. There is strong evidence to suggest that Herbal Medicine has a significant negative effect on Infant Mortality Rate (IMR) in Ondo State. Additionally, the Hosmer-Lemeshow statistic (1.000) suggests that the model fits the data well. Therefore, we accept the alternative hypothesis for IMR.

4.4.2   Test of hypothesis Two

H02: Herbal Medicine Rate (HEM), has no significant effect on Under-five Mortality Rates (U$_5$MR) in Ondo State

The logistic regression results for MAL include a significant p-value (Sig.) of 0.004, and the coefficient for MAL is -7.112. Based on these results, we accept the alternative hypothesis for U$_5$MR. There is strong evidence to suggest that Herbal Medicine has a significant negative effect on Under-five Mortality Rates (U$_5$MR) in Ondo State. Additionally, the Hosmer-Lemeshow statistic (1.000) suggests that the model fits the data well. Therefore, we accept the alternative hypothesis for U$_5$MR.

4.4.1   Test of hypothesis Three

H03: Herbal Medicine Rate (HEM), has no significant effect on Maternal Mortality Rate (MMR) in Ondo State.

The logistic regression results for MAL include a significant p-value (Sig.) of 0.002, and the coefficient for MMR is -26.087. Based on these results, we accept the alternative hypothesis for MMR. There is strong evidence to suggest that Herbal Medicine has a significant negative effect on Maternal Mortality Rate (MMR) in Ondo State. Additionally, the Hosmer-Lemeshow statistic (1.000) suggests that the model fits the data well. Therefore, we accept the alternative hypothesis for MMR.

4.4.2   Test of hypothesis Four

H04: Herbal Medicine Rate (HEM), has no significant effect on life expectancy (LEX) in Ondo State

The logistic regression results for LEX include a significant p-value (Sig.) of 0.004, and the coefficient for LEX is 33.007. Based on these results, we accept the alternative hypothesis for LEX. There is strong evidence to suggest that

Herbal Medicine has a significant positive effect on life expectancy (LEX) in Ondo State. Additionally, the Hosmer-Lemeshow statistic (1.000) suggests that the model fits the data well. Therefore, we accept the alternative hypothesis for LEX.

4.3   Discussion of findings

The logistic regression analysis highlights that Herbal Medicine Rate (HEM) significantly and negatively affecting Infant Mortality Rate (IMR) in Ondo State, with increasing Herbal Medicine Rates correlating with a decrease in Infant Mortality Rate (IMR).

The analysis highlights the significant negative impact of Herbal Medicine (HEM) on Under-five Mortality Rates (U_5MR) in Ondo State, signifying that rising (HEM) is linked to decrease in Under-five Mortality Rates (U_5MR).

The logistic regression analysis reveals that Herbal Medicine (HEM) significantly and negatively impacts Maternal Mortality Rate (MMR) in Ondo State, with higher AMR associated with decreased life expectancy.

The logistic regression analysis reveals that Herbal Medicine (HEM) has a significant positive impacts life expectancy (LEX) in Ondo State, with higher AMR associated with decreased life expectancy.

Overall, the findings from the logistic regression analysis emphasize the substantial impact of Herbal Medicine on economic, health, and societal dimensions in Ondo State, revealing a nuanced interplay between Herbal medicine and health outcomes, viewed through the Grossman Model of Health Demand. This model conceptualizes health as a form of capital that individuals invest in to enhance their well-being and extend their productive lives. The study shows that Herbal medicine positively influences several health indicators, with varying effects on different outcomes. Specifically, Herbal medicine has been associated with reductions in negative health indicators such as infant mortality rate, under-five mortality rate, and maternal mortality rate. These reductions suggest that Herbal medicine, with its culturally relevant and accessible treatments, plays a critical role in improving early-life health and maternal outcomes. This aligns with the Grossman Model's view that investments in health, including Herbal medicine, help reduce adverse health conditions and enhance health capital. As Herbal medicine contributes to lowering these mortality rates, it indicates a positive impact on health, which in turn supports better socio-economic conditions by reducing the healthcare burden on families and communities. On the other hand, the study also reveals a positive relationship between Herbal medicine and life expectancy. The Grossman Model predicts that improving health through effective interventions, such as Herbal medicine, leads to longer, healthier lives. This is supported by the observed increase in life expectancy linked to the use of Herbal medicine in Ondo State.

By extending life expectancy, Herbal medicine not only improves individual well-being but also enhances productivity and economic participation, thereby contributing to broader socio-economic development. The integration of Herbal medicine with modern healthcare approaches has broader socio-economic implications. Improved health outcomes from Herbal medicine reduce healthcare costs and alleviate financial pressures on families, leading to enhanced economic stability and growth. Additionally, Herbal medicine stimulates local economies through activities such as the cultivation of medicinal plants and the establishment of health-related enterprises. This economic stimulation reinforces the positive relationship between health investments and socio-economic development, as individuals with better health outcomes are more likely to contribute productively to their communities. Empirical studies have corroborated these findings, demonstrating that Herbal medicine can effectively improve health indicators and stimulate economic benefits. For instance, similar research has shown reductions in mortality rates and increases in life expectancy in areas where Herbal medicine is prevalent, reflecting its role in enhancing economic stability and growth.

In summary, the positive impact of Herbal medicine on health outcomes such as reduced mortality rates and increased life expectancy underscores its importance in promoting socio-economic development. By improving key health indicators and supporting economic growth, Herbal medicine offers valuable contributions to both individual well-being and community prosperity. Integrating Herbal medicine into broader healthcare systems can thus maximize its benefits and foster a more inclusive and effective approach to health and development.

4.4   Policy Implications

The positive relationship between Herbal medicine and socioeconomic development highlights several critical policy implications that can enhance both health outcomes and economic growth. To fully leverage the benefits of Herbal medicine, it is essential to integrate it with modern healthcare systems. Policies should be designed to facilitate this integration by establishing frameworks that recognize and regulate Herbal practices, ensuring that they meet established

safety and efficacy standards. Such measures will provide accessible and culturally relevant healthcare options, thereby improving overall health outcomes and reducing healthcare costs. Investing in research on Herbal medicine is another crucial aspect. Increased funding and rigorous research are needed to validate the benefits of Herbal practices, providing a solid evidence base for their inclusion in healthcare systems. By understanding the scientific underpinnings of these practices, policymakers and healthcare providers can develop more effective health interventions and policies.

Training programs for healthcare providers should include components on Herbal medicine. Educating practitioners about how Herbal treatments can complement modern care promotes a holistic approach to health, which can enhance patient outcomes and improve the overall quality of healthcare. It is also important to enhance access to Herbal medicine, particularly in underserved areas. Supporting local practitioners and ensuring the availability of Herbal remedies can help address healthcare disparities, leading to improved health outcomes and supporting socioeconomic development. Economic incentives for Herbal medicine can stimulate growth in this sector. Providing subsidies for research, offering tax breaks for health enterprises, and supporting local cultivation of medicinal plants can create jobs and contribute to local economies, further reinforcing the positive economic impact of Herbal medicine. Public awareness campaigns are necessary to educate communities about the benefits of Herbal medicine and its integration with modern practices. Increased awareness helps individuals make informed health choices and adopt preventative measures, ultimately enhancing health and economic benefits. Finally, establishing robust regulatory frameworks to ensure the quality and safety of Herbal medicine practices and products is essential. Such regulations will protect consumers, ensure efficacy, and build public trust, facilitating the effective integration of Herbal medicine into mainstream health systems.

5.1   Conclusion

The study underscores the complex relationship between Herbal medicine and socioeconomic development, highlighting both its potential benefits and limitations. While Herbal medicine positively influences life expectancy by providing accessible and culturally relevant healthcare solutions, its impact on other critical health outcomes, such as infant mortality, under-five mortality, and maternal mortality, can be less favorable compared to modern medical interventions. Integrating Herbal medicine with modern healthcare systems offers a promising approach to enhancing overall health outcomes. This integration can capitalize on the strengths of Herbal practices, such as affordability and cultural relevance, while addressing their limitations through complementary modern treatments. The Grossman Model of Health Demand provides a useful framework for understanding how investments in health, including Herbal medicine, can improve well-being and economic productivity.

To fully harness the benefits of Herbal medicine, it is crucial to support ongoing research to validate its effectiveness, address its limitations, and guide informed policy decisions. Training healthcare providers in both Herbal and modern practices can enhance the quality of care and ensure a more holistic approach to health. Increasing access to Herbal medicine in underserved areas, providing economic incentives for the sector, and launching public awareness campaigns can further contribute to its effective integration and impact.

Establishing regulatory frameworks that ensure the safety, efficacy, and quality of Herbal medicine practices is essential for protecting consumers and facilitating their incorporation into mainstream healthcare. By acknowledging and addressing both the positive and negative aspects of Herbal medicine, the study advocates for a balanced approach that improves health outcomes, reduces healthcare costs, and fosters socioeconomic development, ultimately leading to a more inclusive and effective healthcare system.

5.2   Recommendations

The following recommendations were based upon the findings:

1. Integrate Herbal Medicine into Primary Healthcare Systems: Develop a framework to formally integrate Herbal medicine with modern healthcare services. This approach ensures that Herbal practices complement conventional treatments, enhances accessibility to culturally relevant care, and addresses critical health issues such as infant mortality, under-five mortality, and maternal mortality.
2. Support Comprehensive Research Initiatives: Invest in extensive research to evaluate the efficacy and safety of Herbal medicine practices. Focus on studies that assess their impact on health outcomes like life expectancy and mortality rates. This evidence will help refine practices, validate their benefits, and guide policy-making.
3. Promote Training and Collaboration for Healthcare Providers: Establish training programs for healthcare professionals that encompass both Herbal and modern medical practices. This will foster collaboration between Herbal healers and modern practitioners, leading to more holistic and effective patient care and improved health outcomes.

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4. Develop Regulatory Standards for Herbal Medicine: Implement robust regulatory standards to ensure the quality, safety, and efficacy of Herbal medicine practices. Clear regulations will protect consumers, enhance the credibility of Herbal practices, and facilitate their integration into the broader healthcare system, contributing to overall socioeconomic development.

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TAX LAWS AND SECURITY AS OBSTACLES TO FOREIGN DIRECT INVESTMENT

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Abstract

Critical factors that encourage influx of foreigners to invest their capital in a country are there current laws, security and tax policies. This study examined tax laws and security as obstacles to Foreign Direct Investment (FDI) in Nigeria, at the moment when multinational companies are closing shops or businesses and relocating to nearby countries where tax laws are favorable, due to hash tax laws of the current Nigerian regime. In carrying out this research, a qualitative method or approach was used. This research is a thorough analysis of the existing works, books, economic reports and policy documents. It was discovered that Nigeria is one of the country that charges high corporate income tax compared to its neighboring countries. This high corporate income tax reduces the amount of profit after tax of foreign companies. The application for pioneer status of companies and the procedure for the approval can be lengthy and burdersome, hence discourage FDI inflow into the country. It was discovered also that the worsening security situation in Nigeria due to the activities of Bokoharam, Fulani hader, kidnapping, arm banditry, militancy is responsible for the discouragement of FDI. On the aspect of law, the Local Content Act breaks national treatment found in bilateral investment agreement between Nigeria and other countries. In addition, intellectual property laws are not effectively enforced, making it difficult for foreign investors to protect their rights. This paper recommends that, government should reduce Corporate Income Tax rate, increase of tax holiday period and provide adequate security to stop bokoharam, kidnapping, armed bandit to attract FDI.

Keywords: Corporate income tax; Foreign Direct Investment; Laws; Nigeria; Security

1 Introduction

Countries that depend solely on crude oil sales as their main source of revenue and enhancement of economic growth will certainly have difficulty when the prices of crude oil dwindle in the world market [1]. It is observed that countries with only one source of revenue particularly those that rely only on revenue generated from crude oil to grow their economy would remain exposed to changes, expecially a decrease in price of crude oil. Hence, there is the needs for investment into the different sectors of those economies in order to diversify and absorb shocks on oil volatility. In the bit to diversify, government of such countries have to persuade investors to attract investment inflows or FDI, by providing security, stable and attractive fiscal policies (tax policies). Establishing a legislation and regulation, environment that will wore and bring FDI [2].

Foreign Direct Investment (FDI) is seen to be an essential private external source of finance for countries that are growing like Nigeria. [3] It is also stated that FDI is considered a main source of funds used to bridge the gap produced by a deficit of funds to be generated for domestic investment [4]. Therefore, FDI is an investment carried out by an enterprise that is totally or partially owned by foreigners. Foreign direct investment is regulated in Nigeria through its investment laws, technology, technology transfer law, foreign exchange law, company law, sector specific regulation and international agreements [4] in order to attract foreign direct investment in Nigeria. Unfortunately, some of our taxation policies and laws in the country serve as a challenge or barrier to attract foreign direct investment most especially in this present dispensation of Bola Ahmed Tinubu [5]. These challenges included taxation policies, laws and administration, security and lack of adequate infrastructures to encourage foreign direct investment and domestic investment. The challenges has contributed in preventing FDI and local investors to invest and those who have invested before are divesting.

This shows that the investment cloud in Nigeria is discouraging foreign direct investment due to multiple and unstable tax policies, laws, political and security situation in Nigeria. This research is important most especially in this period

where there are many obstacles or challenges that hamper the attraction of foreign direct investment in Nigeria. Moreover, this study differs from other related studies in Nigeria like [6] who considered the reason why some Nigerian enterprises decided on foreign direct investment and their level of success [7]. The contribution of tax incentive toward the flows of FDI and the effect of such inflows on the Nigerian economy [8]. The appraisal of pioneer status incentives on FDI in Nigeria. [9] Considered the Nigerian treaty network and its impact on foreign direct investment. Similarly, [10] it discusses the influence of Company Income Tax (CIT), excise, and custom duties on FDI, [11] explored taxation and FDI and taxation were proxy by Value Added Tax (VAT) and CIT. Moreover, the above studies used quantitative research. This study used qualitative research and documentary analysis. Nonetheless, the major goal of this study is to examined tax laws and security as obstacles to FDI in Nigeria. This research assessed tax laws and security as obstacles to FDI in Nigeria, This paper is classified into five sections: section one is the introduction, section two deals with literature review and conceptual framework, section three explains the research methodology of the study, section four discusses the discussion of results and section five conclude the paper.

2 Literature Review

Foreign Direct Investment is a resource allocation by individual and corporate entities in a country for business interests sited in other countries. It also occured when a foreigner open a new business or company in a country that is not his own [9]. Empirical literature on FDI has revealed the role taxation policies, security andS laws of a country play in attracting FDI. This is because FDI has many role to perform in improving the economy of developing countiries. Empirical literature usually shows the the needed space in the knowledge gap created to be considered and filled, hence, gives direction for the study. Therefore, Ike [7] had assessed the impact of tax incentives on FDI in Ghana, Nigeria and South Africa and considered the effects of those flows in those countries. The results showed a positive association of tax incentiveon Foreign Direct Investment and that FDI has no significant influence on export in Ghana, Nigeria and South Africa. This means that decrease in corporate tax rate and increase in tax incentives will increase FDI and exports. Nkwanko et al. [8] Concluded that pioneer status application and approval procedure is drawn-out, but the process is cumbersome. Nkwanko et al. Add that, in corporate taxation potential investors who requires prompt decision-making and assurance before investing may be discouraged. Moreover, there are instances where pioneer status programs are interpreted differently by government agencies, thereby creating confusion and impairing investment choices. Appiah-Kubi et al. [12] examined the effect of tax incentives on FDI on African economy from 2000-2018, using econometrical model. The findings indicated that FDI responded to lower CIT. That is FDI predominateS in Africa with long tax holiday and withholding tax, and concluded that achieving poverty reduction and sustainable growth and development, women empowerment will be hindered if proper restructuring of tax incentives to deal with policies lapses by the government are not carried out.

Oyeabo et al. [13] looked at the influence of CIT on FDI in Nigeria. The research design adopted was ex post facto. The results showed education tax and Petroluem Profit Tax (PPT) to have an inversed effect on FDI. Also, the result disclosed a direct influence of CIT on FDI. [14] Thus, an investigation was carried out on the impact of direct tax on FDI in Nigeria, especially the influence of Petroleum Profit Tax, CIT, education tax and Personal Income Tax on FDI. The study disclosed PPT, CIT, and Personal Income Tax (PIT) to have a significant and positive effect on FDIt. However, the outcome of the results between Education tax and FDI is negative [11]. The nexus between taxation and FID was examined in Nigeria. Time series and econometric method was adopted in the data analysis. The results disclosed CIT to have a significant and negative effect on FDI. This showed that an increase in CIT rate leads to a decrease in FDI inflow in Nigeria.

The above discoveries justified why foreign investors do not want to invest in Nigeria and those who have invested are divesting in order to go to countries with low CIT rate. The studies revealed that CIT has a direct effect on FDI. This shows that increase in CIT rate leads to a decrease in FDI in Nigeria as stated in Olakoaga and Osagie, Ali [11], [7].
Similarly, empirical literature on FDI have revealed the role a country's security and law play in attracting FDI. Thus, Alawi and Ali [15] observed that the prevalence of administrative and financial corruption, sagging infrastructures, lack of political and security stability and technological backwardness are obstacles to FDI and domestic investment too [16]. Al-Mahdi and Fisal states the challenges for local investments commission and development solution to encourage FDI in local governments in Irag. The research used mixed method approach and discovered legal, security, weak incentive, administrative challenges and guarantee given by the national investment law in Irag [4]. The research observed a significant effect of national security on FDI in Nigeria and recommended that the Nigerian government should ensure that expenditure on internal and external defense is well utilized appropriately to reduce insecurity to pave way for foreign investors in the country.
[17] The reasons Irag is regarded as the worst place to do business are corruption, lack of security, an unequipped banking system, lack of transparency, intellectual property rights issues, and disputes over oil rights and undeveloped arbitration law. Al-Azzawi and Dulaimi [18] Tried to classify some of the challenges and obstacles of FDI in Iragi and

concluded that foreign direct investors do not want to enter the Irag market due to expulsive investment environments such as insecurity, law and corruption. Hence, Kazar [19] observed that feeble balance pave way for the government to start developing agenda with emphasis on creation of sustainable development plan for the future. The Irag economy most have to be diversify into other sectors of the economy like energy manufacturing of goods and service and energy. This was a broader vision for the resurgence of Irag economy which contributes to the attraction of FDI. Al-Ekhatorand Ayinwe[20] Explored the laws that governed investors investing in Nigeria and uses doctrinal approach to discovered FDI to have positive impact on the various sectors of the Nigerian economy. Thus, the laws regulating the different sectors should be amended to be in line with present realities or globalization. It also, shows that lack of security and law government FDI hinder the inflows of foreign capital into developing economy. Gawzan and Alsamee [2] Used doctrinal research approach and data collected through secondary sources. The research concluded that the provision of information to foreign investors to enable them invest in Irag economy is lacking. And discovered that the draft law on the right to information of 2012 did not contain an article that allow investors right to obtain information they want in relation to laws to invest in Irag. Thus, the study used documentary research and considered the combination of the implications and obstacle of security, law and tax policies on foreign direct investment in Nigeria.

3 Research Methodology

This research adopted a qualitative research design where data were gathered through secondary source and analyze qualitatively. The documentary research involved the analysis of economic reports, reserch articles from journals, existing literature and policy documents. The literature involves a review of literatures, academic articles other relevant publications. The policy documents included contemporary and historical evidence that was also scrutinized to gain a thoroughly understanding of the regulatory framework, policy shift and government initiative that can affect FDI as it is in Kazar [19]. This method was selected because this kind of research involves review, analysis and critism. Data were collected from the first source that was legal document and the second source such as law papers, books and reports as it is in [2].

4 Discussion of Results

The discussion of results on tax policy obstacles to FDI in relation to CIT is that high CIT rate is a drawback to the coming in of FDI into Nigerian economy. Normally, countries that lower their CIT rate serve as an incentive, which give foreign investors opportunity to invest knowing fully that the tax expenses in profit is not much. In Nigeria, the CIT rate is one of the highest in West Africa which is 30 percent of income of corporate organization operating in Nigeria. Followed by Ghana, Senegal, Liberia and Guinea with 25 percent, this is the second highest. Mali, Burkina Faso and Gambia have the lowest rate of 20 percent [12]. This signifies that high CIT rate has been one of the Nigerian greatest obstacles to the coming into the country of foreign investment and hence, investors prefer other West African countries with low CIT to invest and make a huge after tax profit.

Another obstacle to FDI in relation to tax is the tax holiday. Tax holiday is usually giving to industries that are qualified to be be called pioneer companies to be exempted from the payment of CIT for some limited period. Newly established firms are exempted from paying CIT for a specified period [8]. Foreign companies or investors are encourage and always willing to invest in countries with a high maximum number of years as tax holiday. The tax holidays in Nigeria, is the lowest with a minimum of 3 years and a maximum of five years when compared with other West African countries like Senegal, Cote d'ivoire, Ghana and Liberia with a minimum of 5 years and a maximum of 10 years [8], [21]. This shows that Nigeria has the lowest tax holiday period. Thus, the lower tax holiday period serves as an impediment to the attraction of inflows of FDI in Nigeria and hence, investors are discourage to come to Nigeria as a result of that, and prefer to take their investment to those countries with longer period of tax holiday period. Thus, [12] concluded that Foreign Direct Investment flows majorly to African countries with long tax holiday and low rate of withholding tax and VAT. This is what usually enticed the foreigners to come and invest in those countries. Therefore, African nations with low tax holidays and high VAT and withholding tax should try to increase their tax holiday and reduce VAT and withholding tax rates, if they want there countries to be a destination for foreign investment choices in their economies.

The results discovered that security and political stability are fundamental factors in making investment decision or attracting foreign direct investment inflow in a country. The security environment in Nigeria is characterized by serious threat of insurgency, violent extremist groups and heavily armed militia activities in Nigeria. Such as the bokoharam, Fulani herders, armed bandits, Niger Delta militant, and kidnappers remain very active in committing criminal acts. This has given birth to unstable business environment hence; Nigeria remains one of the world dangerous place to invest and to do business with great fear of occurrence of violence, crisis, destruction of life and properties and political instability always. Thus, investors are or will not like to risk bringing their capital and expertise in Nigeria unless they are assured of the security of their life, properties and an economy that is stable devoid of political instability. And those who have already invested are divesting daily. The lack of the security of life and properties, poor economic policy and the current

unstable political situation in Nigeria contributed in hindering many investors to come and invest. This has led to loss of investment in to Nigeria and the inability of the economy to grow and development [22]. [4] This shows that national security has direct effects or encourages and attracts FDI in any nation.

Law and FDI: presently, there is no definate or specific legal instrument or document that deals with Foreign Direct Investment in Nigeria. The law for the establishment, protection and promotion of FID are containing in so legal instrument and many fiscal policy guidelines.. These are Companies and Allied Matters Act (CAMA), security and exchange commission and Nigerian investment promotion commission. Thus, Nigerian investment promotion commission presently Act No. 15 of 1995 (NIPC) as amended in 1998 is the major law regulating FDI in Nigeria. The main aim is to stimulate foreign and local investment [23]. Unfortunately, NIPC is a general legislation on investment rather than law and statutes created to guidelines for investors tobring their investment in Nigeria.

Local contents Act as an obstacle to FDI in Nigeria. The government of Nigeria enacted the local content Act 2010 which gave the indigeneous companies on the oil and gas industry power to control a minimum of 50 percent in oil and gas projects. The act gave Nigerian oil companies to be the main players in giving oil fields and licenses in any subsisting contract in oil and gas sector. The Act, has the responsibility of putting in place a policy guide for continuance and growth of Nigerian local content in the economy through a balance programmed of planning, motoring, target setting, creating jobs and improving contractors capability. Unfortunately, it is observed that the local contents Act is against other clauses in investment obligation, national treatment and international agreements. [24]. Moreover, the World Trade Organization is one of the international agreements that the local content Act provision contravenes. In addition, [24] it is argued that the local content Act is not in tendom with national treatment put in bilateral treaties on investment as it concerns Nigeria. This shows that the local content Act has to be altered to be in-turn with the current economic realities accentuated by globalization. The inability to amend this law has contributed in limiting the influx of FDI in Nigeria. [20] A close examination of laws that government various sectors of the economy disclosed that many laws are besotted with some limitation or obstacles that impede the meaningful application of FDI in Nigeria and concluded that the alteration of the extent laws regulating the different sectors to promote the inflow of FDI in Nigeria is necessary.
Intellectual property law can be an obstacle to FDI. This is because the Nigerian intellectual property laws are not effectively enforced, making it difficult for foreign investors to protect their rights. There are also widespread counterfeit and piracy of product software and creative works are available in the country, inadequate legal laws and lack of specific legislation for current and emerging technology hinders FDI coming into the country.

The legislative obstacles that regulate the dealing with foreign investor (FDI) laws in Nigeria are not clear and some instances they conflict with each other legislation, inadequate guarantees of freedom to transfer profit discourages FDI flow in Nigeria. Those that have invested before are pulling out of the country. Other obstacles are; corruption; financial and administrative corruption deter both foreign investment and local investment. The investor goes away from areas where corruption takes place regularly, because investing in such areas contribute in increasing the cost of the project. The government officials and employees usually demands for the payment of bribe during the process of doing business. This art normally discourage foreign investors from investing. Moreover, when you look at the corruption index rating in the world, you will discover Nigeria to number 145 out of 180 countries in transparency international report in the year 2023 in corruption perception index. Nigeria receives a score of 25 out of 100 points, indicating a high level of perceived corruption [25].

Infrastructures; the result shows that Nigeria has a weak and lack of infrastructures due to corruption, insecurity and lack of political will as majority of the infrastructural projects executed are of low quality due to usage of low or substandard materials that are below the standards specified in the contract agreements, no good roads, railways etc.

5 Conclusions

The main goal of the research was to examine whether tax laws, security serves as an obstacle to FDI in Nigeria. According to the findings of the study, there are many obstacles and challenges that have and are currently preventing foreign investors to come and invest their capital in Nigeria. These are:
Nigeria charges high corporate income tax rate compared to its neighboring countries which reduces the amount of profit after tax the companies will make and hence discourage FDI inflow into the country. Pioneer status application and approval procedures can be delayed and burdensome. Will be foreign investors who needs protection and immediate decision-making before investing their hard earn funds in Nigeria may be deterred. Moreso, there are instances where so many government parastatals manage and interpret the pioneer status arrangement differently. The difference in approach usually leads to confusion and impair the selection of investment distination in the counrty. Moreover, the pioneer status in Nigeria is the lowest compared to other West African countries and hence, investors always select countries with long pioneer period to invest. Hence, investors prefer countries with long period of tax holiday to invest. It was discovered

that the worsening security situation in Nigeria as a result of the activities of bokoharam, Fulani haders, kidnapping, army banditry, militancy is responsible for the discouragement of Foreign Direct Investment. On the aspect of law, the local content Act was said to have violates national treatment of investorsas as it is found in bilateral investment agreements as concerns Nigeria. This shows that the local content Act has to be repelled to be in-turn with the current economic realities accentuated by globalization. The inability to amend this law has contributed in limiting the coming in to Nigeria of foreign investor funds for direct investment.

The Nigerian intellectual property laws are not effectively enforced, making it difficult for foreign investors to protect their rights. There are also widespread counterfeit and piracy of product software and creative works are available in the country, inadequate legal laws and lack of specific legislation for current and emerging technology hinders foreign direct investment into the country. Administrative bottlenecks and financial corruption in the point of registration and application for pioneer company discourages FDI inflows.

5.1 Recommendations

Nigerian government should reconsider reducing its corporate income tax rate and make it attractive for foreign investors to make Nigeria to be the destination for FDI. Nigerian government with low corporate income tax holidays or pioneer period for foreigners coming to open their new businesses should as a matter of urgency come up with tax policy that will increase their corporate income tax holiday or pioneer periods for newly created companies in order to encourage foreign investment selection in its favor.

Government should makesure that money budgeted for purchase of equipments and technology to track and end insecurity of life and properties are utilized and directed to the necessary quarters to achieve the motive to which they were provided for. This will end insecurity and encourage the coming in of foreign direct investors in the country. Moreover, the government should motivate our security men to boast their morale to fight insecurity so as to ensure national security of life and properties and peace of mind for all categories of people leaving in the country.

Government should amend the local content law and make provisions that will encourage foreigners to invest their capital in the country. The Nigerian intellectual property laws should be enforced to give confidence to foreign investors to come and invest knowing fully that they can also protect their right when the need arise.

The government should makesure they work tirelessly to remove administrative bottleneck in the process of establishing new companies, financial corruption and ensure transparency and accountability in the process. This will encourage and attract foreigners and local investors to invest their funds in the economy. Government should as a matter of urgency reduces adminitrative red tape and streamline the application process for granting pioneer status.

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EXPLORING THE INFLUENCE OF TAXATION ON NIGERIA'S ECONOMIC GROWTH: AN IN-DEPTH ANALYSIS

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ABSTRACT

This study examined the impact of taxation on economic growth in Nigeria for the period 2003 to 2023. The study was based on the ex-post facto research design and the expediency theory of taxation. To achieve the study objective data were gathered on Gross Domestic Product (GDP) as dependent variable and components of taxation in Nigeria including Companies Income Tax Revenue (CIT), Customs Duties Revenue (CUD), Value Added Tax Revenue (VAT), and Petroleum Profit Tax Revenue (PPT). The study conducted both the pre-estimation and post estimation tests for the variable's trending, unit root, cointegration, causality, normality and stability. Furthermore, an ARDL model was used to determine the variable's parameters and p-statistics test was employed to examine their significance. The results obtained shows that Company income tax (CIT) has an insignificant negative impact on economic growth such that a unit change in CIT, tend to decrease GDP by N30914.88 billion; Custom duty (CUD) has a significant negative impact on economic growth such as a unit change in CUDR, tend to decrease GDP by N340888.2billion; Value added tax (VAT) has a significant positive impact on economic growth such that a unit change in VATR, tend to increase GDP by N483495.3 billion; and Petroleum profit tax (PPT) has an insignificant negative impact on economic growth such that a unit change in PPTR, tend to decrease GDP by N19280.79 billion. The study recommends among others that the Nigerian government should reform the company income tax system to make it more efficient and less burdensome on businesses, particularly small and medium-sized enterprises (SMEs). This could include reducing the tax rate, streamlining the tax filing process, and providing tax incentives for businesses that invest in research and development, innovation, and job creation.

Keyword: Gross Domestic Product, Companies Income Tax Revenue, Customs Duties Revenue, Value Added Tax Revenue, and Petroleum Profit Tax Revenue

1 INTRODUCTION

Taxation plays a crucial role in promoting economic and social activities and growth of countries, both developing and developed because it serves as one of the major sources of their revenue. According to Organisation for Economic Co-operation and Development (OECD) (2021), United State government revenue from taxes accounts for over 50 per cent of all government revenue since the past decade, and accounted for $3.42 trillion generated in 2020 by the government. It has been ranked as a major source of revenue in countries such as UK, France, Sweden, Norway, and other high-income countries. In Africa, tax revenue has significantly contributed towards the economic growth of different countries. Weigel (2020) show that people are more willing to engage with public affairs when revenue is sourced through taxation. Tax payments should be obligatory, non-negotiable and binding on all citizens of a country regardless of religion and social status. (Anthony, 2016).

Through taxation, government ensures that resources are channeled towards important projects in the society while giving support to the weak. Orjih (2001) stated that taxation is useful in raising revenue, controlling the consumption of certain commodities, controlling monopoly, reducing income inequalities, improving the balance of payments as well as protecting infant industries. Taxes are used in modern time to generate revenue. They are applied to fund governance generate employment, ensure resource redistribution and stimulate growth in the economy. Tax has two basic functions.

Tax creates a major and regular source of revenue to meet the government's spending needs. The mandatory nature with wide impact of tax is an important basis for the government to mobilize financial resources timely and sufficiently from the economy. Tax is also a tool to regulate the economy. By the means of tax, the government regulates the behaviour of enterprises and individuals, thereby directing production and consumption. A reasonable tax policy will promote economic growth, whereas an unreasonable tax regime will constrain enterprises and distort society's consumption behaviour (Nguyen, 2019). Tax is a significant tool of fiscal and economic policy.

Nigeria, taxation has been in existence even before the coming of the colonial men or the British (Samuel and Tyokoso, 2014). The critical burden hindering the Nigerian economy is how to diversify its revenue generation base (Adegbie, 2011); which has consistently depended on the earnings from crude oil. The Nigerian economy may go down the drain if alternative sources of revenue generation are not urgently made towards sustaining the drive for diversifying the revenue base of the economy. The demand for Nigeria's crude in international market has reduced by major oil consuming nations of the world. This is not a good pointer for the country which depends on oil revenue for its survival and sustainability. However, the resultant problem of tax generation in Nigeria is the issue of appropriate data to capture all tax payer's information, and when such taxes are collected, they seem to be majorly diverted through the pipes of corruption thereby reducing its significant impact on economic growth. Also, because of this, most tax payers are demotivated to pay taxes believing that such taxes will not be adequately utilised in creating the needed economic growth which results in cases of tax evasion and tax avoidance. However, this study aims to investigate the impact of taxation on economic growth in Nigeria. The objectives of the study are therefore: (i) Examine the impact of Companies Income Tax on Economic Growth in Nigeria. (ii) Determine the impact of Customs Duties on Economic Growth in Nigeria. (iii) Evaluate the impact of Value Added Tax on Economic Growth in Nigeria. (iv). Assess the impact of Petroleum Profit Tax on Economic Growth in Nigeria. The rest of the study is presented as follows: section 2 presents the literature review involving the theoretical underpinning of the study and the review of empirical studies. Section 3 focuses on material and methods which captures the data and model specifications. Section 4 analyses the data and divulges the findings, while sections 5 concludes the paper and highlights the recommendations.

2.0 REVIEW OF RELATED LITERATURE

2.1 Conceptual Framework

2.1.1 Taxation

Taxation is the transfer of resources as income or revenue from the individual, corporation and private sector to the public sector for its utilization to achieve some if not all the nation's economic and social goals such as provision of basic amenities, social services, educational facilities, public health, transportation, and capital formation. According to Nigeria's National Tax Policy (NTP, 2020), a tax may be seen as a levy or charge that has been imposed on individuals or legal entities by a given state or authorized body in a state. It explains a monetary burden that has been placed on property and individuals to support government spending.

Taxation is an important fiscal policy instrument at the disposal of governments to mobilise revenue and promote economic growth and development. Governments use tax revenue to carry out their traditional functions such as the provision of public goods and services; maintenance of law and order; defence against external aggression; and regulation of trade and business to ensure social and economic maintenance. The Institute of Chartered Accountants of Nigeria (2016) and the Chartered Institute of Taxation of Nigeria (2012) defined tax as an enforced contribution of money to government pursuant to a defined authorized legislation. In other words, every tax must be based on a valid statute. Without a valid statute no legitimate tax can be imposed. Tax is a method of raising the revenue for the day to day running of government activities. Government activities involve generating funds and using same to provide security, social amenities, infrastructural facilities, etc., for the inhabitant of the country. Base on this, it is worthy of note that the objective of taxation is in tandem with the functions of government (Akhor, 2016).

2.1.2 Economic Growth

Economic growth can be defined as the sustained increase in a country's productive capacity, and per capita national output or net national product over a while. These increases are the basic causes of economic growth. Fiscal policy is one of the most important tools that have a significant effect on all economic sectors and have a real effect on economic variables like the Gross national product, inflation, unemployment, etc. Taxes can be seen as a fiscal policy, macroeconomic, and internal revenue mobilization tool for the attainment of economic growth. Economic growth can be proxied, using different economic indicators, ranging from Gross National Product (GNP), Gross Domestic Product (GDP), Human Development Index, and Per Capita Income. But in this study, economic growth was measured with Gross Domestic Product (GDP), and Human Development Index (Salami, 2015).

Economic growth has been major concern of nations whether developed or developing around the world. Economic development and Economic growth have been used interchangeably over the years; despite the slight difference between the two concepts. According to Organisation for Co-operation and Development (OECD), economic development is a deliberate policy intervention aimed at enhancing the economic and social well-being of people, while, economic growth is a phenomenon of an active market productivity resulting in increase in Gross Domestic Product (GDP) (Organization for Economic Cooperation and Development, 2014).

Gross Domestic Product (GDP) is a monetary measure of the market value of all the final goods and services produced in a period, often annually or quarterly. "An aggregate measure of production equal to the sum of the gross values added of all resident and institutional units engaged in production (plus any taxes, and minus any subsidies, on products not included in the value of their outputs)" (OECD, 2014). GDP measures the monetary value of final goods and services—that are bought by the final user produced in a country in a given period of time (say a quarter or a year) (IMF, 2016).

2.2. Theoretical framework

2.2.1 Expediency Theory of Taxation

This study is anchored on the expediency theory of taxation propounded by Buehler (1936). The theory stated that every tax collection system must pass the test of practicability, which must be the only consideration when government is choosing a revenue collection system. The assumption of this theory is that the economic and social objectives of the government should be treated as irrelevant, since it is useless to have a tax which cannot be levied and collected effectively (Chiamaka, Obinna, Friday and Oraekwuotu, 2021).

The theory believes in the effectiveness and efficiency of tax collection and its instruments so as the needed revenue would be collectively generated, the theory also believes in the power of tax in remedying economic and social ills of the society bridging the gap in income inequality, regional disparities and how taxation can be used to fight unemployment which forms the bases for this study; solving revenue issues of government, providing solutions to economic woes of the country through taxation.

2.3 Empirical Review

El-Shagi (2020) examined the nexus between taxation and Economic Growth in Nigeria. The study employed a Survey of the Literature and Variables used include Tax revenue, GDP, inflation, unemployment. The study found that the relationship between taxation and economic growth is complex and depends on various factors such as the level of economic development, tax structure, and institutional quality. The study recommended that Policymakers should consider the impact of taxation on economic growth and implement tax reforms that promote sustainable economic development.

Bakar (2020) investigated the impact of corporate taxation on economic growth for 20 developed countries over the period 1990-2015. Variables Used include Corporate tax rate, GDP, GDP growth rate, inflation rate, and government expenditure. Panel data regression analysis using the system GMM estimator was employed. The re A 1% increase in the corporate tax rate is associated with a 0.15% decrease in GDP growth rate. The study recommended that governments should consider reducing corporate tax rates to stimulate economic growth.

Bank-Ola (2021) examined the impact of VAT on economic growth in Nigeria from 1999 to 2019. The ARDL model was employed using time series data. The result of the analysis in the short run, showed that VAT has a negative and significant effect on economic growth whereas in the long run, the effect was positive but insignificant on economic growth. Inflation also has a significantly positive effect, whereas interest rate has a significantly negative effect on economic growth in the long run. The study concludes that in the long run, a positive relationship exists between VAT and economic growth in Nigeria.

Onoja and Ibrahim (2021) examined the relationship between tax revenue and Nigeria economic growth. In order to achieve this objective, data was gathered through secondary means. Tax revenue is proxy by PPT, VAT and CIT, while economic growth is proxy by GDP. The study revealed that PPT has a positive but no significant relationship with Nigeria economic growth, while VAT and CIT have significant relationship with Nigeria economic growth.

3.1 MATERIALS AND METHODS

The study adopted the ex-post facto research design. The study evaluated the impact of taxation on economic growth in Nigeria. The study used archival data whose manifestations have already occurred and the researcher cannot manipulate the outcome. The study scope is 2003– 2023 and data were sourced from the statistical bulletin of the Central Bank of Nigeria 2023.

3.2 Model Specification

This study adapted the model of El-Shagi (2020) who examined the nexus between taxation and Economic Growth in Nigeria with modifications. His study employed variables including GDP, Tax revenue, inflation and unemployment stated functionally as:

GDP =f (TXR, IFR, UER) …………………….. ………….…………….…. . . . . . (3.3)

Where:
GDP = Gross Domestic Product (proxy of Economic Growth)
TXR = Tax Revenue
IFR = Inflation Rate
UER = Unemployment Rate

Equation 3.3 is modified by replacing its variables with those of the current study and restated thus:

GDP = f(CIT, CUD, VAT, PPT) -   -   -   -   -   -   -   (3.4)

Where:

GDP = Gross Domestic Product
CIT = Companies Income Tax Revenue
CUD = Customs Duties Revenue
VAT = Value Added Tax Revenue
PPT = Petroleum Profit Tax Revenue

$GDP = \alpha + \beta_1 CITR_t + \beta_2 CUDR_t + \beta_3 + VATR_t + \beta_4 PPTR_t + U_t$ …………………….….………. (3.5)
Where:
α = Constant Intercept
$\beta_1, \beta_2, \beta_3, \& \beta_4$ = Parameter Estimates
U_t = Stochastic Error Term

The model parameter estimates ($\beta_1, \beta_2, \beta_3, \& \beta_4$) are expected to bear positive (+) signs such that they have positive impact on economic growth.

4.1 Data Analysis and Discussions
The data used for this study are presented in appendix A attached. These include time series on Gross Domestic Product (GDP), Companies Tax Revenue (CIT), Customs Duties Revenue (CUD), Value Added Tax Revenue (VAT), and Petroleum Profit Tax Revenue (PPT) the periods 2003 to 2023 in Nigeria

4.1.1 Regression Results

Table 4,1: ARDL Short-Run Regression Results

ECT(-1)*	-0.818804	361.6788	-5.028782	0.0000

Table 4.4: Long-Run ARDL Regression Results

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	8028759.	11917982	0.673668	0.5054
CIT(-1)	-30914.88	56008.17	-0.551971	0.5848
CUD(-1)	-340888.2	116566.9	-2.924399	0.0063
VAT(-1)	483495.3	44114.85	10.95992	0.0000
PPT(-1)	-19280.79	10356.41	-1.861724	0.0718
R-squared	0.958098	Mean dependent var		1.05E+08
Adjusted R-squared	0.952860	S.D. dependent var		1.94E+08
S.E. of regression	42114293	Akaike info criterion		38.07476
Sum squared resid	5.68E+16	Schwarz criterion		38.29245
Log likelihood	-699.3831	Hannan-Quinn criter.		38.15151
F-statistic	182.9195	Durbin-Watson stat		1.828431
Prob(F-statistic)	0.000000			

Source: Author's Computation with the use of E-view 12.00, 2024

GDP = 8028759 - 30914.88CIT - 340888.2CUD + 483495.3VAT - 19280.79PPT -0.818804ECT   (4.1)

From the long –run estimated equation, with the exception of the sign of VAT which conformed to the model apriori expectation by being positive, the signs of the rest of the variables (CIT, CUD, and PPT) did not conformed to the model apriori expectation by being negative. This means that while VAT positive impact, CIT, CUD and PPT have negative impact on economic growth proxy by GDP in Nigeria during the period under investigation,

The coefficients of CIT (-30914.88), CUD (-340888.2), VAT (+483495.3), PPT (-19280.79) implies that holding other variables constant, a unit change in CIT, CUD, VAT and PPT tend to decrease GDP by N30914.88 billion, decrease GDP by N340888.2billion, increase GDP by N483495.3 billion and decrease GDP by N19280.79 billion respectively. Furthermore, the value of the constant intercept (8028759) shows that in the absence of any change in the value of the independent variable the GDP remained fixed at N8028759 billion.

The coefficient of multiple determination (R^2) of 0.958098 means 95% of variation in GDP was accounted by changes in the independent variables (CIT, CUD, VAT and PPT). The remaining 5% unexplained variation in GDP are accounted by the error term. This shows the good fit of the ARDL model.

The coefficient of ECT (-0.818804) which is negative with probability value (0.0000) less than 0.05, shows suggest that the speed of adjustment is when the model is disturbed it will return to short term equilibrium at the speed of 81%. This means that approximately 81 per cent discrepancy is corrected each year.

The F-statistics coefficient of (182.9195) which has a chi-square probability value (0.0000) suggest that a significant changes in the value of the independent variable (GDP) where jointly accounted for by changes in the independent variables (CIT, CUD, VAT and PPT).

The Dubin-Watson statistics (1.828431) is closer to the acceptable minimum value of 2.00 suggest that the model is free of serial correlation.

4.2 Estimation Test Results

4.2.1 Unit Root Test Result

The Augmented Dickey Full (ADF) Unit root test conducted on the time series variables used in this study shows the

result in table 4.1 below.

Table 4.2: Augmented Dickey Fuller (ADF) Test Result

Variables	ADF T-Value	5% Critical T-Value	p-value	Order of Integration
GDP	-3.287668	-2.991878	0.0270	I (0)
CITR	-3.593089	-2.998064	0.0142	I (1)
CUDR	-3.073674	-2.960411	0.0391	I(0)
VATR	-3.550638	-2.963972	0.0133	I (1)
PPTR	-3.012401	-2.998064	0.0486	I (1)

Source: Author's Computation with the use of E-view 12.00, 2024

The Augmented Dickey Fuller (ADF) unit root test results in table 4.2 reveals that when tested at level, I(0), GDP and CUDR both have calculated ADF t-values less than their critical t-value at 5% level of significance. But variables, CITR, VATR and PTTR have ADF t-values greater than their critical T-Value at 5% level. The study therefore, accept H_0 and conclude that GDP and CUDR have no unit root and are stationary at level but reject H_0 and conclude that variables CITR, VATR and PTTR have unit root and are not stationary at level. This therefore, calls for the test at first difference.

When tested at first difference however, the results show that all the variables, GDP, CITR, CUDR, VATR and PPTR have calculated ADF t-statistics values which are greater than their critical t-values at 5% significant level. The study therefore, accept H_0 of no unit root and conclude that the variables are stationary at first difference. This was also confirmed by the respective probability values of the variables which are all less than 0.05.

The mixed stationarity of the variables, some at I(0) and others at I(1) indicated the presence of their long-run relationship. Hence, the ARDL regression technique becomes applicable to the study.

4.2.2 Co-integration (Bound) Test Results

Table 4.3: ARDL Co-integration Bound Test Results

ARDL Bounds Test
Null Hypothesis: No long-run relationships exist

Test Statistic	Value	K
F-statistic	8.225445	4
Critical Value Bounds		
Significance	I(0) Bound	I(1) Bound
5%	**3.84**	**5.02**

Source: Author's Computation with the use of E-view 12.00, 2024

The bound test for cointegration result obtained in table 4.3 shows that the calculated F-statistics (8.225445) was greater than the critical upper bound (5.02) and the critical lower bound (3.84) at 5% level of significance. The study therefore, reject H_0 of no cointegration and conclude that the study variables have long-run relationship among themselves. Since the result established that there is co-integration (long-run relationship) between the variables under study, the ARDL regression technique can be confidently employed to estimate their parameters.

4.2.4 Causality Test Result

Table 4.4: <u>Pairwise Granger Causality Test Results</u>

Null Hypothesis:	Obs	F-Statistic	Prob.	Decision	Causality Nature
CIT does not Granger Cause GDP	35	2.95465	0.0374	Reject H_0	Bidirectional
GDP does not Granger Cause CIT		10.2070	0.0004	Reject H_0	
CUD does not Granger Cause GDP	35	3.18671	0.0456	Reject H_0	Unidirectional
GDP does not Granger Cause CUD		3.77155	0.0646	Accept H_0	
VAT does not Granger Cause GDP	35	16.6318	0.0105	Reject H_0	Unidirectional
GDP does not Granger Cause VAT		1.33029	0.2796	Accept H_0	
PPT does not Granger Cause GDP	35	0.56830	0.0425	Reject H_0	Unidirectional
GDP does not Granger Cause PPT		0.90965	0.4135	Accept H_0	

Source: Author's Computation with the use of E-view 12.00, 2024

The granger casualty test results in table 4.4 shows that the P-values (0.0374, 0.0456, 0.0105 and 0.0425) for the causal relation between variables, GDP, CIT, CUD, VAT and PPT are respectively less than the standard P-value (0.05). The study therefore, reject H_0 and conclude that there exist a causal relationship running from the independent variables (GDP, CIT, CUD, VAT and PPT) to the dependent variable (GDP).

The results further shows that the causal reverse relationship between dependent and independent variables have their P-values (0.0004, 0.0646, 0.2796, and 0.4165) which are greater than the standard P-value (0.05). The study therefore, accept H_0 and conclude that there is no causal relationship running from the dependent variable (GDP) to the independent variables (CIT, CUD, VAT and PPT).

The results obtained implies that there exist a unidirectional causality running from the independent variables (CIT, CUD, VAT and PPT) to the dependent variable (GDP) and the reverse causality was not possible for any of the independent variables.

4.3   Discussion of Findings

First the study found that company income tax (CIT) has insignificant negative impact on economic growth proxy by GDP in Nigeria. This means that an increase in CIT does not have a statistically significant effect on GDP. There are several possible explanations for this finding: CIT is a complex tax with many loopholes, which can lead to tax evasion and avoidance. As a result, the tax revenue generated from CIT may not be as high as expected, reducing its impact on economic growth; CIT may not be an effective incentive for investment in Nigeria, as companies may not perceive it as a significant deterrent to investment. This could be due to other factors such as corruption, bureaucracy, and political instability; and Companies may choose to invest in alternative channels, such as foreign markets or other industries, rather than being deterred by CIT. This finding corroborates the findings of earlier studies done by Jibrin et al (2012), Musa et al. (2018); Adeniran (2020); Etim et al. (2020); Isaac et al., (2020) and disagrees with the work of Onoja and Stephen (2020).

Secondly, the study found that custom duty (CUD) has significant negative impact on economic growth proxy by GDP in Nigeria. This suggests that an increase in CUD leads to a reduction in GDP. This finding can be attributed to several factors including the fact that CUD can be seen as a trade restriction, which can reduce the volume of imports and exports. This can lead to reduced competition, higher prices, and lower economic growth; CUD can lead to the inefficient allocation of resources, as businesses may divert resources away from productive activities to comply with customs regulations; CUD can reduce economic efficiency by creating barriers to trade and investment, leading to reduced economic growth. This finding is in line with the findings of earlier studies done by Musa et al. (2017); Musa et al. (2018); Uket et al. (2020); Kaoje et al. (2020); Obaretin and Uwaifo (2020); Kareem et al. (2020); Mukolu and Ogodor (2021).

The study also found that value added tax (VAT) has significant positive impact on economic growth proxy by GDP in Nigeria. This suggests that an increase in VAT leads to an increase in GDP. There are several possible explanations for this finding including the fact that VAT is a consumption-based tax, which means that it is more likely to generate revenue from domestic consumption rather than foreign trade. This increased revenue can be used to finance public goods and services that stimulate economic growth; VAT is often seen as a more efficient and effective tax compared to other taxes, such as CIT. This improved tax administration can lead to increased government revenue and reduced

corruption; VAT can be seen as a more business-friendly tax compared to other taxes, which can lead to increased investment and economic growth. This finding is in consonance with the work of Iduh et al. (2019); Adegbie et al. (2020); Awa and Ibeanu (2020); Todorovi et al. (2020); Okolo et al. (2021); Gbeke and Nkak (2021); and contradicts the works of Osho and Efuntade (2019); Aliyu and Mustapha (2020); Etim et al. (2020).

Finally, it was found that petroleum profit tax (PPT) has insignificant negative impact on economic growth proxy by GDP in Nigeria. This suggests that an increase in PPT does not have a statistically significant effect on GDP. There are several possible explanations for this finding including the fact that Nigeria's economy is heavily dependent on oil revenues, which may reduce the impact of PPT on economic growth; The petroleum industry is highly regulated and capital-intensive, which may limit the scope for investment and innovation; and Other factors such as agricultural production, manufacturing, and services may be driving economic growth in Nigeria, reducing the impact of PPT. This finding is in line with the findings of earlier studies done by Akhor et al. (2016); Nwanakwere (2019); Tanchev (2021) and contradicts the study of Pamba (2022) and disagrees with the work of Ibanichuka et al. (2016); Adegbie et al. (2020).

5.1 Conclusions

Taxation is of strategic importance in achieving increased income and enhanced economic growth in Nigeria. One of the main purposes of taxation is to raise revenue that the government can use to provide adequate amenities and infrastructure as well as enhance growth and development. But, the case seems to be different. It is evident from the empirical results of this study that having evaluated the contribution of taxation to economic growth, this study concludes that taxation indeed has contributed positively to the income of the government and invariably to economic growth. The study found that while company income tax (CIT) has an insignificant negative impact on economic growth, custom duty (CUD) has a significant negative impact. On the other hand, value added tax (VAT) has a significant positive impact on economic growth, while petroleum profit tax (PPT) has an insignificant negative impact. These findings suggest that policymakers should consider reforming taxation policies to promote economic growth in Nigeria. Specifically, they should consider:

5.2   Recommendations

Based on the study findings the following recommendations are considered imperative;

   i.   Government should reform the company income tax system to make it more efficient and less burdensome on businesses, particularly small and medium-sized enterprises (SMEs). This could include reducing the tax rate, streamlining the tax filing process, and providing tax incentives for businesses that invest in research and development, innovation, and job creation.
   ii. The tax authority should review and reduce the tariffs on imported goods to reduce the burden on businesses and consumers. This could help increase competition, reduce prices, and increase economic activity. Additionally, consider implementing a more efficient and transparent customs clearance process to reduce bottlenecks and delays.
   iii. The board of internal revenue should continue to implement and expand the Value Added Tax (VAT) system to encourage businesses to invest in value-added activities and stimulate economic growth. Consider increasing the VAT rate slightly to increase government revenue, but ensure that the rate is still competitive with neighbouring countries.
   iv. The government should consider reducing the Petroleum Profit Tax rate to encourage oil companies to increase investment in exploration and production activities, which could lead to increased oil production and revenue for the government. Additionally, consider implementing tax incentives for oil companies that invest in local communities and prioritize local content development.

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Appendix (A)
Data Presentation, Analysis and Interpretation:

Year	GDP	CIT	CUD	VAT	PPT
2003	13418012.90	114.80	195.50	136.40	683.50
2004	17938381.18	113.00	217.20	159.50	1183.60
2005	22884896.39	140.30	232.80	178.10	1904.90
2006	30063962.40	244.90	177.70	221.60	2038.30
2007	34318665.73	275.30	241.40	289.60	1600.60
2008	39542427.56	420.60	281.30	401.70	2060.90
2009	43012507.43	600.60	297.50	481.40	939.40
2010	54612264.18	666.10	309.20	564.89	1480.40
2011	62980397.22	654.50	438.30	659.15	3070.60
2012	71713935.06	820.60	429.60	710.56	3201.30
2013	80092563.38	963.50	570.90	802.68	2666.40
2014	89043615.26	1173.50	646.70	802.96	2454.00
2015	94144960.45	1269.00	636.40	767.33	1290.00
2016	101489492.20	933.50	750.50	828.20	1157.80
2017	113719048.23	1215.10	694.60	972.30	1520.50
2018	352300000.61	1340.30	679.50	1108.00	2467.60
2019	268476400.00	1604.70	785.90	1190.00	2114.30
2020	273654100.00	1275.40	884.80	1531.20	1517.00
2021	629800000.40	1748.00	1005.50	2072.90	2008.50
2022	717130000.90	2150.90	1262.50	2589.60	2867.40
2023	717130000.90	2150.90	1262.50	2589.60	2867.40

Source: CBN, NBS and FIRS bulletins

IMPACT OF NON INTEREST FINANCIAL SERVICES ON HOUSEHOLDS' INCOME AND SAVINGS

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Abstract. This paper examines and assesses the impact of non-interest financial services on household livelihood as indicated by the improvement in the households' income and savings. A total of 750 client households were randomly selected from the seven states in the Northwest region of Nigeria. Intuitively, the study considered two dimensions through which the impact could be felt; namely; change in households' income and savings. The paper employs logistic regression model in its analyses. The result of the empirical estimations shows that the household's change in income model is significantly influenced by household's size, gender of the household head, current facility amount, number of repayment installments, the type of account maintain with the non interest financial service providers and membership in a cooperative society. In the household's savings model, the study found that religion, household size, income, operating a mudarabah savings account, type of the non interest facility enjoy and membership in a cooperative society increases household's savings habit, and therefore, improve livelihood. Lastly, the study posits that measures aimed at improving access to non-interest financial services, especially for women, is capable of enhancing livelihood in the study area.

Keywords: non-interest, financial-services, household, livelihood

1 Introduction

The overriding recognition of the complex make up of livelihood has resulted in many new modalities and more comprehensive programmes that address not only the replacement of physical assets, but the restoration of crucial social networks, provision of financial services, and development of markets (Kofarmata & Danlami, 2021). The first step for building self-sufficiency and a sustainable livelihood is re-establishing the necessary assets for income generation. Without an income, individuals and households are obliged to depend on family, friends and other available avenues of assistance to meet their most basic needs. Where help is limited, many are forced to resort to adverse coping mechanisms, such as cutting down on meals or selling off any remaining productive assets. Without assets, earning opportunities decrease and many are forced to migrate for menial work or take on overwhelming debt. To prevent this spiral cycle of vulnerability, it is imperative to act swiftly to protect the assets people have and replace or rebuild those that have been lost (United Nation Development Programme [UNDP], nd). Furthermore, it is generally agreed that assets ownership and household wealth accumulation significantly improve the livelihood and welfare of households. This implies that the higher the number of assets and the amount of wealth accumulation, the better the livelihood of the households. However, households in the Northwest region of Nigeria have minimal possession of assets for better livelihood. In fact, in most cases, the households in the region do not even possess the basic home assets for day-to-day livelihood based on the data provided by National Bureau of Statistics (NBS, 2020).

Programming and funding for livelihood support is channeled through multiple sectors, and livelihood practitioners struggle to develop effective coordination mechanisms and tools to assess needs, evaluate impacts, and prevent overlapping and conflicting interventions. However, many of these programmes have been mostly ad-hoc and poorly sustained (Bashir & Danlami, 2022). Moreover, poverty in the Northwest region of Nigeria is so pervasive to the extent that two states (Sokoto and Jigawa) in the Northwest region occupy the first and second positions of having the highest percentage of household living below the poverty line. In Sokoto State, 87.73% of households are poverty-stricken while that of Jigawa State is 87.02% (NBS, 2020). On a positive note, Kaduna State, in the region, recorded the least percentage of 43.5% of households living below the poverty line (NBS, 2020).

Therefore, inability of households to attain livelihoods could lead to vulnerability, malnutrition, impoverishment, and often resulting in negative coping strategies for survival. For instance, evidence shows that the average daily calorie

intake per person in the region is about 1,300 calories which is much lower than the global daily average calorie intake of 2700 calories (Danlami et al., 2016; Kofarmata & Danlami, 2019). The situation is further aggravated by lack of ability to raise credit for investment in livelihood activities. This poverty trend indicates the need for higher financial inclusion of individuals in the Northwest zone to improve the livelihood of people in the area.

Against this background, this study investigates the impact of non interest financial services on the livelihood of households in the Northwest Region of Nigeria. The remaining parts of the paper are explained as follows. Section two is the literature review, section three explained the methodology of the paper. Sections four and five contain presentation of empirical findings and conclusion and recommendations, respectively.

2 Literature Review

A sustainable livelihood paradigm is framed on five independent and interrelated factors which consist of: physical, natural, social, human and financial (Department for International Development [DFID], 2001). Incidentally, these assets of livelihood coincide with the objectives of Islamic law known as *Maqasid-Shari'ah* which Islamic jurists such as Imam Al-Ghazali, and also Dusuki and Abozaid (2007) whose arguments are in course to ensuring justice in the societal socio-economic living. Evidences indicated that Islamic financing and investment systems incentivize more ethical and economically required behaviours causing poverty alleviation by way of embracing non-interest financial resources (Al-Harran, 1999; Dhumale & Sapcanin, 1998; Akhtar, 1998; Ahmed, 2001; El-Gamal, 2006 & Miazur, 2010).
Specifically, Bangladesh Institute of Development Studies (BIDS) (2001) conducted a study on microcredit, the study reported that there was a positive relationship between the microcredit and the income of the participants. In the same vein, Zaman (2001) assessed the impact of microcredit on poverty reduction and households' savings. The findings revealed that microcredit increases voluntary savings and reduces poverty among women and increases women's decision making ability.

Furthermore, a study by Amin et al. (2003) on the impact of three Islamic microfinance programmes on rural poverty eradication title: ASA Financial, Bangladesh Rehabilitation Assistance Committee (BRAC) and microcredit clients of Grameen Bank, the study concluded that the microcredit programmes were more successful in terms of reaching the poor. Moreover, Miazur (2010) concluded that productivity of crops and livestock, household income, as well as employment and expenditure of beneficiaries of Islamic microfinance facilities in Bangladesh, increased significantly as a result of the influence of changed behaviour and availability of the Islamic Microfinance. Additionally, Larry (2016) empirically established that; proper financing of non-interest transactions determines the trend of poverty reduction in Nigeria. In addition, Bhuiyan et al. (2015) empirically found that credit access significantly improved sustainable livelihood of customers of the Islamic bank microfinance schemes in Bangladesh as well as reduced the poverty incidence of same. Furthermore, the level of beneficiary's education, household savings and total amount of loan received, were among the significant determinants of livelihood status of the borrowers. Similarly, Ahmed et al. (2015) opined that the Islamic financial sector has the potential to contribute to the achievement of the Sustainable Development Goals (SDG) as long as the principles of Islamic finance that support socially inclusive and development activities. This conforms to the study by Hoffmann et al. (2018) who assed impact of government-sponsored livelihoods projects among households and women in India. The results indicated that there is significant positive impact on assets ownership among households.

Furthermore, Danlami et al. (2024) in their preliminary investigation on non interest financial services and household livelihood concluded that the factors that might have significant impact on the livelihood of the clients of non interest financial services include: household head gender, access to the non interest facility, age, household size cost of obtaining the non interest facility and the years of business experience. Being a preliminary study, the study recommended further in-depth empirical investigation on this concept.
Lastly, Jailos (2019) empirically examined the impact of financial inclusion on the livelihood of rural households in Tanzania. The results showed that, financial inclusion has a positive significant impact on rural livelihoods in Tanzania. Easy access to formal banking services leads to positive changes in the rural livelihood status of households. The study recommends aggressive strategy on financial inclusion to reduce poverty and financial access vulnerabilities. This is consistent with the findings of Bilal et al. (2020) who found a positive relationship between microfinance services and livelihood.

3. Methodology

In view of the fact that the paper studies households at the micro level, this section contains the description of the methods used in data gathering as well as the model used by the study as the tool of data analysis.

3.1   Sampling and Data Source

The sampling technique used in this study is the two-stage cluster sampling. In the first stage, the whole of the study area were divided into seven clusters on the basis of the States' boundaries of the Northwest region namely; Jigawa, Kaduna, Kano, Katsina, Kebbi, Sokoto and Zamfara states respectively. In the second stage, from each of the seven clusters (i.e., states) a total of 100 respondents were randomly selected from the clients of non interest financial services excluding Kano State, whereby by a total of 150 respondents were randomly selected. This gives the total of 750 respondents selected as the samples of the study

3.2   Model Specification

Literature is replete with application of logit model when a researcher is confronted with discrete data. Accordingly, logit model was used to assess how provision of non-interest services by financial institutions improved the livelihood of the clients in terms of change in income, consumption and savings behaviors of the clients. Following Danlami et al. (2017) and Gujarati (2004), the theoretical logit model can be expressed as follows:

$$P = E\left(Y = \frac{1}{X_I}\right) = \frac{1}{1 + e^{-(\beta_1 + \beta_2 X_i)}} \tag{1}$$

For ease of expression if $\quad z = \beta_1 + \beta_2 X_i$

$$P = \frac{1}{1 + e^{-z_i}} = \frac{e^z}{1 + e^z} \tag{2}$$

If P represents the probability of occurrence (say improvement in livelihood), the probability of not occurrence can be expressed as:

$$1 - P = \frac{1}{1 + e^{z_i}} \tag{3}$$

Hence the odds ratio between the probabilities of occurrence and non-occurrence can be expressed as:

$$\frac{P}{1 - P_I} = \frac{1 + e^{z_i}}{1 + e^{-z_i}} = e^{z_i} \tag{4}$$

Where: Pi/(1-Pi) represents the odds ratio of improvement in livelihood. That is the ratio of the probability that a household experiences improvement in livelihood to the probability of otherwise. Taking the natural log of equation (4) we obtained the following expression as:

$$L_i = \ln\left(\frac{P_i}{1 - P_i}\right) = Z = \beta_1 + \beta_2 X_i \tag{5}$$

Where:
L means the log of odds ratios, equation (5) represents what is known as the logit model which is used when the dependent variable takes a binary value; 0 or 1.

3.3   Specification of the Empirical Logit Models

Leveraging on the applications of logistic regression models by numerous researchers, this study draws from the models by Miazur (2010) Khan (2014) and Bhuiyan et al. (2015) Danlami et al. (2024) and integrated a number of important variables to suit the purpose of this investigation. Here, the logistic regression model seeks to assess the impact of investment from non-interest facility and other determinants on household's income. The dependent variable is the

change in the level of income witnessed by the beneficiaries of non-interest facility. The household change in income model is specified as:

$$Ln\left(\frac{P_i}{1-P_i}\right) = \beta_o + \beta_1 AGE_i + \beta_2 HHS_i + \beta_3 MSTATUS_i + \beta_4 GND_i + \beta_5 CFA_i + \beta_6 NRPI + \beta_7 LOC_i + +\beta_8 BEX_i +$$
$$\beta_9 TINCB_i + \beta_{10} TINCA_i + \beta_{11} INVNIF_i + \beta_{12} NTNIF_i + \beta_{13} ACT_i + \beta_{14} NAB_i + \beta_{15} NAA_i + \beta_{16} MCS_i +$$
$$U_i \qquad (6)$$

Where:

P_i = probability that the income of clients increases

$1 - P_i$ = probability of otherwise

AGE_i	**=**	**Age of the head of the borrower**
HHS_i	=	Size of the household
MSTATUS_i	=	Marital status of the household head
GND_i	=	Gender of the head of the borrower
CFA_i	=	Current facility amount
NRPI_i	=	Number of repayment instalments
LOC_i	=	Location
BEX_i	=	Years of business experience
TINCB_i	=	Total income before non interest facility
TINCA_i	=	Total income after receiving a non interest facility
INVNIF_i	=	Investment in non interest facility
NTNIF_i	=	Number of times non interest facility received
ACT_i	=	Account type
NIFA_i	=	Non-interest facility access
NAB_i	=	Number of assets owned before patronising non interest financial service
NAA_i	=	Number of assets owned after patronising non interest financial service
MCS_i	=	Membership of cooperative society

$\beta_1, \beta_2 \ldots \beta_{16}$ are the coefficients of the regressor variables to be estimated. The constant term or intercept of the regression model is denoted by β_o while U_i symbolizes the error term.

3.4 Household Saving's Model

The empirical model to be estimated for the change in the household savings as a result of patronizing the non-interest facility is expressed as:

$$Ln\left(\frac{P_i}{1-P_i}\right) = \beta_o + \beta_1 GND_i + \beta_2 REL_i + \beta_3 AGE_i + \beta_4 MSTATUS_i + \beta_5 HHS_i + \beta_6 INC_i + \beta_7 LOC_i + +\beta_8 BEX_i +$$
$$\beta_9 ACT_i + \beta_{10} TNIF_i + \beta_{11} INVNIF_i + \beta_{12} MCS_i + U_i \qquad (8)$$

Where:

P_i = probability that the savings of clients increases

$1 - P_i$ = probability of otherwise

GND_i	**=**	**Gender of the head of the borrower**
REL_i		Religion of the household head
AGE_i	=	Age of the head of the borrower
MSTATUS_i	=	Marital status of the household head
HHS_i	=	Size of the household
INC_i	=	Income of the household head
LOC_i	=	Location
BEX_i	=	Years of business experience
ACT_i	=	Account type
TNIF_i	=	Type of non interest facility
INVNIF_i	=	Investment in non interest facility

MCSi   =   Membership of cooperative society

$\beta_1, \beta_2 \ldots \beta_{12}$ are the coefficients of the regressor variables to be estimated. The constant term or intercept of the regression model is denoted by β_o while U_i symbolizes the error term.

4. Results and Analysis

This section conducts analysis of the estimated results. The analyses conducted in different subsections are as follows:

4.1. Frequency distribution analysis

In this section, the socio-demographic characteristic of the respondents were analysed using a frequency distribution table. Also, the section analyses non interest financial services and inclusion as well as the household livelihood strategies using frequency distribution tables. Table 1 indicates the frequency distribution of the various respondents based on their socio-economic characteristics.

Table 1: Socio-Economic Characteristics of Respondents

Characteristics	Frequency	Percentage	Cumulative Percentage
Gender			
Male	575	79.64	79.64
Female	147	20.36	100
Age			
18 – 29	136	18.8	18.8
30 – 39	276	38.28	57.14
40 – 49	177	24.55	81.9
50 - 59	100	13.87	95.56
60 and above	32	4.44	100
Marital Status			
Single	157	21.75	21.75
Married	565	78.25	100
Religion			
Islam	684	94.87	94.87
Christianity	36	4.99	99.86
Others	1	0.14	100
Level of Education			
Non formal Education	107	14.84	14.84
Primary School	73	10.12	24.97
Secondary	171	23.72	48.68
Diploma/NCE	163	22.61	71.29
B.Sc./HND	157	21.78	93.07
Postgraduate	50	6.93	100
Occupation			
Civil servant	158	22.25	22.25
agriculture	201	28.31	50.56
knowledge-based	23	3.24	53.80
manufacturing	22	3.10	56.90
extractive	26	3.66	60.56
wholesale/retail	134	18.87	79.44
Professionals	46	6.48.	85.92
services	26	3.66	89.58
Others	74	10.42	100
Monthly Income			
Less than ₦30000	142	19.75	19.75
₦30000 -₦60,000	173	24.06	43.81
₦61000 -₦90000	156	21.70	65.51
₦91000 - ₦120000	115	15.99	81.50

Above ₦120000	133	18.50	100
Household Size			
1 – 5	269	38.54	38.54
6 – 10	244	34.96	73.50
11 – 15	92	13.18	86.68
16 - 20	67	9.60	96.28
21 and above	26	3.72	100

Source: Authors (2024)

Table 1 indicates the socio-economic characteristics of the respondents. It is indicated that about 80 percent of the respondents are male. This is because most of the household heads are male based on cultural norms of the people in the region. Additionally this is indicating the gender gap in terms of financial inclusion in the region of the study as the samples of the study were randomly selected from the customers of the non interest financial service providers. Additionally, about 79 percent of the respondents are married, this is in line with the cultural practice of the region as the people of the region attach higher value to marriage. They perceived that marriage make the couple to be more responsible. Furthermore, about 95 percent of the respondents are Muslims. This is because Northwest region is the region of Nigeria that are dominated by Muslims. Also, since the respondents were selected from the clients of non interest financial service providers, definitely Muslims are the most patronisers of such services as interest transaction is vehemently condemn in Islam. Similarly, 82 percent of the respondents claimed to earned less N120,000 with some even earning less than N30,000. This is in line with expectation because most of the people in the region are living in extreme poverty. In fact based on the data from NBS (2023), the region constitutes the two States in the country with the highest rate of people leaving in extreme poverty.

Table 2: Non Interest Financial services and Inclusion

Characteristics	Frequency	Percentage	Cumulative Percentage
Having Investment in any NI-financial institution	174	25.51	25.51
Yes	508	74.49	100
No			
Accessibility to NI-Facility			
Highly accessible	10	1.69	1.69
Accessible	26	4.41	6.10
Neutral	65	11.02	17.12
Fairly accessible	221	37.46	54.58
Poorly accessible	268	45.42	100
Request for Financing from NI-Financial Institutions	543	80.56	80.56
Yes	131	19.44	100
No			
Type of Account have in NI- Financial Institutions	266	38.95	38.95
Current Account	392	57.39	96.34
Savings Account	20	2.93	99.27
Mudarabah Investment Account	5	0.73	100
Wakalah Investment Account			
Number of times NI loan/facility received	2	0.39	0.39
Zero	326	63.18	63.57
One	123	23.84	87.40
Two	54	10.47	97.87
Three	7	1.36	99.22
Four	3	0.58	99.81
Five	1	0.19	100
Six			
Non-Interest Facility			
Mudarabah Financing			22.48
Musharakah Financing	127	22.48	25.49
Murabaha Financing	17	3.01	92.39

Ijarah Financing	378	66.90	94.34
Al-Qqard Al-hasan	11	1.95	95.04
Salam Financing	4	0.71	99.12
Istisna'a Financing	23	4.07	99.82
Other services	4	0.71	100
	1	0.18	
Type of Non-Interest financial service provider	646	90.73	90.73
Full pledge Islamic bank	16	2.25	92.98
Conventional bank with non-interest bank window	6	0.84	93.82
Islamic micro finance	0	0	0
Islamic fund managers	44	6.18	100
Takaaful			
Mode of Repayment Instalment			
Monthly	337	64.19	64.19
Bimonthly	7	1.33	65.52
Quarterly	49	9.33	74.86
Semi-annually	14	2.67	77.52
Annually	32	6.10	83.62
Others	86	16.38	100

Source: Authors (2024)

Table 2 indicates the frequency distribution analysis of non interest financial services and inclusion in the study area. The Table indicates that the majority of the respondents (75 percent) claimed that they don't have any investment with any non interest financial institution. Hence they are totally clients of these institutions and this is in line with a priori expectation as most of the people in the region are poor, they fighting for daily survival and therefore cannot have extra resources for investment in the mentioned financial institutions. In the same vein about 83 percent of the respondents claimed that they have difficulty in accessing non interest financial service such as Mudarabah and the likes and therefore, they are mere account holders in these non interest financial institutions. This is expected as most of the people living in the region are extremely poor and therefore cannot scale through the risk assessment of these financial institutions so that they easily provide such non interest financial services to such people. However, of those that claimed to enjoy a non interest financing service, most of the claimed to received Murabah financing service based on cost plus mark up method in which they payback in a monthly instalments. Similarly, 96 percent of the respondents claimed that they have either savings or current account with such financial institutions. Only less than 4 percent claimed to have investment accounts in the form of either Mudarabah or Wakala Investment accounts.

Table 3: Livelihood strategies

Characteristics	Frequency	Percentage	Cumulative Percentage
Membership in cooperative society			
Yes	249	42.28	42.28
No	340	57.72	100
Increase in income due to NI-Facility			
Strongly Agree	14	2.24	2.24
Agree	62	9.90	12.14
Neutral	108	17.25	29.39
Disagree	199	31.79	61.18
Strongly Disagree	243	38.82	100
Consumption enhancement due to NI-Financial Institutions			
Strongly Agree	4	0.62	0.62
Agree	62	9.58	10.20
Neutral	141	21.79	31.99
Disagree	242	37.40	69.40
Strongly Disagree	198	30.60	100

Number of Assets owned before NI facility	305	66.74	66.74
25 and below	110	24.07	90.81
26 - 50	28	6.13	96.94
51 - 75	6	1.31	98.25
76 - 100	8	1.75	100
Above 100			
Number of Assets owned After patronising NI facility			
25 and below			60.53
26 - 50	273	60.53	85.14
51 - 75	111	24.61	94.46
76 - 100	42	9.32	96.90
Above 100	10	2.44	100
	14	3.10	
My savings increased as a result of Type of NI financial service provider			
Strongly Agree	26	4.70	4.70
Agree	84	15.19	19.89
Neutral	143	25.86	45.75
Disagree	161	29.11	74.86
Strongly Disagree	139	25.14	100
Wealth Increase from NI facility			
Strongly Agree	16	2.66	2.66
Agree	71	11.81	14.48
Neutral	93	15.47	29.95
Disagree	213	35.44	65.39
Strongly Disagree	208	34.61	100

Source: Authors (2024)

Table 3 indicates the distribution of livelihood strategies of the respondents. Most of the respondents argued that they don't participate in any cooperative society. This is not unusual in the study area as most people are not aware about the benefit of being in to a cooperative society. Additionally, the Table shows that the majority of the respondents (about 70%) disagree with the fact that their income increased due to being client of non-interest financial institutions. This is not surprising because most of these clients are mere account holders in such NI-Financial institutions. Most of them did not receive any form of NI-Facility such as Mudarabah etc. (apart from being an account holder) and therefore at the end of the day, being customers of such financial institutions could not change their income status. Nearly same response rates were found regarding the impact of the NI Financial institutions on other livelihood indicators such as: enhancement in consumption, increase in savings, change in the number of assets own and the total wealth increase. Most of the respondent did not report any significant changes of these livelihood indicators as a result of the activities of NI-Financial Institutions. This is as explained earlier due to the fact that most of the customers are mere account holder and owners with these NI-Financial Institutions and could not access the various actual NI-Interest facilities that may have a positive impact on their livelihood.

4.2 Inferential analysis of the relationship between non interest financial services and the household livelihood

Furthermore, Table 4 indicates the estimated logit model of the impact of non-interest financial service on the household livelihood indicated by the change in the household income. This is indicated below:

Table 4: Household change in income models

	(1) Coefficients	(2) Odd Ratios
VARIABLES	Change in Income	Change in Income
Age	-0.0277	0.973
	(0.0265)	(0.0258)
Hhs	0.109**	1.115**
	(0.0437)	(0.0487)
Mstatus	-1.241**	0.289**

	(0.549)	(0.159)
Gender	1.376***	3.960***
	(0.532)	(2.105)
Current_facility _amount	3.24e-06***	1.000***
	(1.14e-06)	(1.14e-06)
no_repay_instal ments	-0.161***	0.851***
	(0.0493)	(0.0419)
Location	-0.166	0.847
	(0.522)	(0.442)
Years of business experience	-0.0295	0.971
	(0.0873)	(0.0848)
total_income_b 4_ni_fs	-6.20e-05***	1.000***
	(1.87e-05)	(1.87e-05)
total_income_a fter_ni_fs	5.66e-05***	1.000***
	(1.85e-05)	(1.85e-05)
investment_in_ ni_fi	-0.636	0.530
	(0.556)	(0.294)
no_tmes_ni_fac ility_obtained	-0.614	0.541
	(0.389)	(0.211)
1.acc_type	0.933*	2.541*
	(0.546)	(1.387)
2.acc_type	-0.340	0.712
	(1.176)	(0.837)
no_ast_own_be fore	0.0292**	1.030**
	(0.0145)	(0.0149)
value_ast_own _before	-1.52e-08	1.000
	(6.05e-08)	(6.05e-08)
Membership of coop society	1.243***	3.466***
	(0.460)	(1.594)
Constant	0.297	1.346
	(1.377)	(1.853)

Note: Robust standard errors in parentheses *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 5 shows the estimated logit model for the relationship between non interest financial services and the household livelihood as measured by change in income. Based on the estimated result of the change in income model, the coefficient of household size was found to be statistically significant at 5% level. The result shows that this coefficient has a positive relationship with the improvement in household livelihood. A one unit increase in the family size will lead to increase in the log odd of household livelihood improvement by about 0.11 units, all things being equal. This is in line with a priori expectation because based on the culture of the people of the study area, larger family size tend to have higher income because most of the able family member tend to engage in one or more income generating activity which at the end of the day increases the overall family income. This is tally to the findings of Danlami et al. (2024). Additionally, the estimated result of household change in income model indicates that the coefficient of marital status was found to be statistically significant at 5% level. The estimated discrete effect of this variable was found to be negative which indicates that when the married client of non-interest financial institutions has lower log odd of improvement in his livelihood by about 1.24 units compared to the non married client. This is in line with a priori expectation because in some instant, married client divert part of the facilities received from those non interest financial institutions and used them to cater for family needs instead of re-investment which may affect their income flow unlike the non married clients whereby in most cases they do not have much family responsibilities and therefore channeled the facilities directly to where they were meant for.

Moreover, the discrete effect of the variable gender was found to be statistically significant at 1% level. This variable was found to be positive indicating that a male gender clients of the non-interest financial institutions tend to have higher log odd of improvement in livelihood by about 1.38 units compared to the their female counterparts. This is in line with a priori expectation because of the economic domination of male gender over the female gender in the study area which gives them more chance of investment opportunities. However, this contradicts the findings of Mirach and Hailu (2014). Furthermore, the coefficient of amount of current facility was found to be positive and statistically significant at 1%. Based on the estimated result, a ₦10,000 increase in the amount of current facility obtained from the non interest financial institutions will lead to increase in the log odd of household livelihood improvement by about 0.32 units all things being equal. This conforms to the a priori expectation because, the larger the facility obtained, the larger the investment/capital consequently the higher will be the change in income. This contradicts the findings of Danlami et al. (2024). Moreover, the estimated model indicates that the coefficient of variable number of repayment installment was statistically significant at 1% level. This coefficient was found to be negatively related with the log odd of improvement in income implying that the higher the number of repayment installment for a non-interest facility, the lower the log odd of household improvement in livelihood by about 0.161 units all things being equal. However, this finding does not conform to a priori expectation but supports the findings of Danlami et al. (2024)

Furthermore, the coefficient of variable income earned before enjoying any non-interest facility was found to be negative and statistically significant at 1% level. Based on the estimated result, a ₦10,000 increase in the amount of income before enjoying a non-interest facility is associated to a decrease in the log odd of household livelihood improvements by about 0.6 units all this being equal. This is contrary to a priori expectation. Contrarily, the estimated coefficient of variable number of assets before patronizing non interest financial services was found to be positive and statistically significant at 5% level. The estimated value of this coefficient indicates that a household that has larger number of assets by one unit tend to experience improvement in the log odd of their livelihood by about 0.03 units all things being equal. This is in line with a priori expectation because the non interest financial services tend to have more impact on households that already have some assets than poorer and impoverished households. On the same vein, the estimated odd ratio of this variable was found to be significant at 5% level. The value of the estimated odd ratio indicates that households that have higher number of assets prior to the non interest financial services have higher odd of improvement in livelihood via change income by about 1.03 times higher. This is in line with a priori expectation.

Similarly, the estimated coefficient of variable membership of cooperative society was found to be positive and statistically significant at 1% level. Based on the estimated value of this coefficient, a household that belongs to a particular cooperative society tend to have higher log odd of livelihood improvement from non interest financial services by about 1.243 units compared to those that do not belong to any cooperative society. This finding is in line with a priori expectation because the households that belong to a particular cooperative society tend to enjoy more non interest financial services and also can bargain for more benefits which may have more impacts on household livelihood. This finding conforms to the findings of … Furthermore, the estimated odd ratio of this coefficient was found to be positive and statistically significant at 1% level. Based on the value of the estimated odd ratio, the odd of livelihood improvement from non interest financial services for households that are members of a cooperative society is about 3.47 times higher than those who do not belong to any cooperative society. This is in line with a priori expectations.

Moreover, Table 5 indicates the estimated model for household livelihood improvement as measured by the household change in savings. The estimated coefficients and the odd ratios are shown in the following table:

Table 5: Household Change in Savings Model

VARIABLES	(1) Coefficients Change in Savings	(2) Odd Ratios Change in Savings
gender	-0.223	0.800
	(0.335)	(0.268)
religion	-1.762**	0.172**
	(0.781)	(0.134)
age	-0.0128	0.987
	(0.0150)	(0.0148)
Marital status	0.0645	1.067
	(0.217)	(0.231)
Household size	0.0759**	1.079**
	(0.0297)	(0.0320)
income	7.77e-06*	1.000*
	(4.67e-06)	(4.67e-06)
location	0.262	1.299

	(0.314)	(0.408)
Years of business experience	0.0454	1.046
	(0.0468)	(0.0490)
1.acc_type	0.786***	2.195***
	(0.286)	(0.627)
2.acc_type	1.803*	6.067*
	(1.062)	(6.441)
3.acc_type	0.294	1.341
	(2.301)	(3.086)
1.ni_facility	-1.743**	0.175**
	(0.789)	(0.138)
2.ni_facility	0.488	1.630
	(0.326)	(0.531)
3.ni_facility	1.064	2.899
	(0.784)	(2.271)
5.ni_facility	0.274	1.315
	(0.589)	(0.774)
6.ni_facility	1.907*	6.730*
	(1.045)	(7.032)
inv_in_ni_fi	0.0122	1.012
	(0.318)	(0.322)
Membership of coop society	1.557***	4.744***
	(0.263)	(1.248)
Constant	-2.286***	0.102***
	(0.638)	(0.0649)
Observations	429	429

Note: Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Furthermore, Table 5 indicates the various coefficients and odd ratios of estimated logit model for the household livelihood improvement vis change in the household savings as a result of enjoying non interest financial services. The estimated logit model indicates that the coefficient of religion was found to be statistically significant at 5% level. The estimated value of this coefficient indicates that Muslim Clients have higher log odd livelihood improvement from the non interest financial services by about 1.76 units than otherwise. This is in line with a priori expectation because most of the clients of non interest financial services in the study area are Muslims and therefore the impact of these services will be much higher on Muslims than otherwise. Moreover, the estimated odd ratio of this variable was found to be significant at5% level. The estimated value of the odd ratio indicates that the odd of household change in savings from non interest financial services for the clients that are non Muslims is 0.172 times lower than that of the clients that are Muslims.

Additional, the estimated result indicates that the coefficient of household size was positive and statistically significant at 5% level. The estimated value of the coefficient indicates that a one unit increase in the household size will lead to increase in the log odd of household livelihood improvement by about 0.076 units all things being equal. This is in line with a priori expectation because, after enjoying a non interest facilities, in most cases the clients use some of their family members as a source of free labour supply for their business, this save the labour cost, increases the earning and savings consequently leading to livelihood improvement. This also conforms to the findings of ,,, In the same vein, the estimated odd ratio of this coefficient was found to be statistically significant at 5%. Based on the estimated value of the odd ratio, a one unit increase in the size of the household leads to increase in the odd of household livelihood improvement by about 1.079 times higher, this is in line with the a priori expectation. Similarly, the estimated coefficient of income was found to be positive and statistically significant at 10% level. The result indicates that increase in income of the clients by ₦1000 leads to increase in the log odd of the household's livelihood improvement by about 0.008 units all things being equal. This is in line with a priori expectation because when income increases under normal circumstances part of it is usually goes to saving this is also in line with the theory of absolute income hypothesis.

Moreover, the coefficients of account type maintain by the clients of non interest financial services were found to be positive and have significant impact on the household livelihood. Based on the estimated result, the clients that operate savings account with the non interest financial service providers tend to have higher log odd of household livelihood improvement by about 0.786 units compared to those that operate current accounts. In the same vein, the odd ratio for household livelihood improvement for the clients that maintain savings account is 2.195 times higher than those operate

current account with the non interest financial service providers. Both the odd ratio and the coefficient of this category were found to be statistically significant at 1% level. Also, the households that maintain Mudarabah Account with the non interest financial service providers have higher log odd of livelihood improvement by about 1.8 units compared to those who maintain current account all things being equal. So also, the estimated odd ratio of this coefficient was found to be statistically significant at 10% level. The estimated value of the odd ratio indicates that the clients of non interest financial services that maintain Mudarabah account experience increase in the odd ratio of household livelihood improvement by about 6. 07times higher compared to those that maintain current account.

Lastly, membership in one or more of the various cooperative societies was found to be positive and statistically significant at 1% level. The result indicates that the clients of non interest financial services that are members in a cooperative society have higher log odd of livelihood improvement through the change in savings by about 1.557 units than other wise. This is in line with the a priori expectation due to the fact that those clients that have membership in a cooperative society enjoy many privileges when dealing with the non interest financial service providers which have more impacts on their livelihood than those who do not have membership in any cooperative society. This is in line with a priori expectation and also conforms with the findings of …Furthermore, the value of the estimated odd ratio of this coefficient was also found to be positive and statistically significant at 1% level. Based on the estimated result, the clients that have membership in a cooperative society enjoy more livelihood improvement through improve in savings with the odd ratio which has value of 4.74 times higher than those clints with no membership of any cooperative society.

5. Conclusion

This paper conducted an empirical analysis of the impact of non interest financial inclusion and services on the household livelihood in the Nortwest Nigeria. The paper empirically analyses two dimensions that reflect improvement in the household livelihood namely; change in the household income and savings. The estimated model of household change in income indicates that the larger the size of the household the higher would be the impact of non interest financial inclusion and services on the livelihood of the client household. Also, households that are headed by male gender tend to experience more impact of such services on the livelihood than otherwise. In the same vein, it was found that current facility amount, number of assets owned before and having membership in at least one cooperative society. On the other hand, based on the estimated model for household change in savings, it was found that size of the household has a positive impact on the change in savings and that the higher the level of income, the more livelihood improvement due to change in savings. This is in line with the axiom of absolute income hypothesis. Also, it was empirically established that the clients that have at least one membership in a cooperative society tend to experience improvement in livelihood than otherwise.

6. Recommendations

Based on the findings of the study, the following practices were recommended:
Instructive from the findings is the fact that measures aimed at easing access and cost of non-interest financing, especially for large families could induce positive impact on livelihood.
Reducing gender imbalance in access to Islamic financial services is capable of improving household consumption cum livelihood.
Islamic banks should also consider household enterprises with more years of business experience in their dealings.
Furthermore, there is a need to encourage the clients to subscribe or form some cooperative societies as this will make non interest financial services to have more impacts on the livelihood of the clients. Through cooperative societies, the clients are in a better position to bagain more and thereby getting more from the non interest financial services. Lastly, the client should stick more to savings and mudarabah accounts than current account as these accounts have more impact on the livelihood of the clients.

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Understanding cyber threats in an era of digitally connected classrooms: Lessons for the Nigerian higher education system and society

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Abstract

This review explores the risks associated with digital instructional practices, mainly focusing on the implications of cyber threats in higher education digitally connected classrooms and society. Although advancements in technology have enabled the development and use of diverse and adaptable teaching methods and societal endeavours, their impact during and after COVID-19 has also introduced or escalated cyber threats in higher education digitally connected classrooms and society, necessitating a review of approaches to teaching, learning and social engagements in today's digitally rich environment. This review aims to identify the cyber threats confronting digitally connected higher classrooms and society, revealing their various forms in higher education or social environments. The review underscores the importance of continuous engagement with educators and social awareness programs as part of addressing cyber threats in higher education and society. The author concludes by offering valuable insights to help shape resilient digitally connected higher instructional systems in Nigeria.

Keywords: Cyber threats, digitally connected classrooms, higher education, learning, society, teaching

1. Introduction

The emergence and widespread use of digital technology during and after the COVID-19 pandemic profoundly impacted higher education globally, sparking innovative changes and necessitating digitally connected educational practices [78]. For example, the advanced use of technology during and after the COVID-19 pandemic encouraged digitally connected educational practices, where teaching and learning occurred in the same or different spaces, facilitating flexible teaching plans and self-motivated and personalized learning experiences [36, 73, 81]. Additionally, digitally connected educational practices, which incorporate the use of interactive and interconnected teaching and learning technologies such as interactive mobile devices, smartboards, internet-oriented tablets, internet-enabled laptops, virtual laboratories, and the Internet of Things (IoT), are transforming instructional plans, connecting lecturers and students for real-time informative and collaborative engagements [29, 75].

For example, some of these digitally motivated technologies during the COVID-19 pandemic have continued to gain momentum in higher education [9, 35], even till date. Digitally connected classrooms are also described as using electronic and digitally motivated technologies such as smart mobile devices, smartboards, software, tablets, laptops, virtual laboratories, personal use of own devices and data bundles to generate, store and process information or knowledge or learning resources on course lessons in ways in which communications are initiated and knowledge of subject matter is shared [35, 75]. Moreover, [39] and [11] posited that digitally connected resources offer opportunities for flexible, affordable, collaborative, and innovative teaching strategies that employ technology to achieve curriculum objectives and allow students to learn quickly in digitally connected classrooms.

Furthermore, the increased use of digitally connected technologies in digitally rich classrooms now helps extend teaching methods to create new opportunities for teaching and learning purposes in virtual or physical spaces for educational and personal development [12, 35, 39]. For example, [49] and [54] argued that the disruptive nature of digital technology, which includes rapid advancements and changes in the internet landscape, has recently necessitated rapid adaptation to learning and teaching in online environments, making learning and teaching possible from different locations and accessing resources or information in the cloud. Similarly, the study by [39] on the role of digital technologies in education argued that adapting digital technologies as a platform for connected teaching helps maintain students' collaborative, equal engagement and provides effective feedback in virtual settings.

However, the advanced use of digitally connected technologies for educational practices from 2020 and beyond (the COVID-19 pandemic periods and after) has also brought sensitive and heightened debates regarding the threats associated with the use of digital technologies for connected education practices. In other words, [24], [41] and [46] contend that risks associated with teaching and learning in virtual spaces via digital technologies, otherwise known as cyber risk, remains a concern for educators and higher education stakeholders, generating debates for critique, condemnation, repositioning, subjection, and research. The cyber risk, also known as cyber threats in higher education,

includes unauthorized access to information from students, educators and institutional administrators [10, 62, 74, 24], sometimes leading to attacks on higher-level institutions' administrative secrets or documents, with higher concentrations of stored sensitive data, intellectual property, cutting-edge research outputs, and personal data from staff and students, making higher education vulnerable to phishing, theft and electronic ransomware attacks [10, 53, 76].

Additionally, [13], [7], [59] and [61] reasoned that recent advancements in artificial intelligence (AI) have led to the introduction of large language models, such as ChatGPT (Chat Generative Pretrained Transformers), Blender Bot 2.0, DALLE-E, Fireflies, Tome, Bard, BERT, and RoBERT. These large language models, collectively known as open AI tools, have brought opportunities to connect classroom teaching, learning and administrative practices in higher education. From their viewpoint, [13] opined that OpenAI tools offer benefits such as content generation, language translation, scientific research, assignment development, and virtual assistants for knowledge development and writing guidance. However, the researcher agreed with [26] that the use of OpenAI tools in higher education threatens intellectual property by storing and reproducing users' information as solutions for others, leading to potential plagiarism and ethical concerns. While OpenAI tools have the potential to revolutionize learning and teaching practices, researchers contend that their use may also undermine educators' creative pedagogical approaches focused on critical thinking and fact-checking.

Furthermore, the challenges associated with using OpenAI in interconnected higher education practices include a lack of transparency, privacy concerns, and the potential for cyber abuse among students, educators, and administrators [26, 2]. Unfortunately, these risks can lead to social and cognitive misalignments and unethical practices in higher education and society [14]. One other concern is that these large language models are trained on vast amounts of internet-sourced text data, making it difficult for them to fully understand or investigate the quality and biases of the information they disseminate [38]. Moreover, the use of large language models in instructional practices encourages unintentional plagiarism risk, which the author called OpenAI-giarism, as users may unknowingly rely on and reuse generalized information without acknowledgement, which is highly unacceptable in higher education. Although large language models such as Open AIs offer significant opportunities for innovation, their use in interconnected higher education classrooms, whether in the Global South or North, also brings about substantial cyber risks or threats to teaching and learning, influencing human moral development and sustenance in society and higher education [7, 66].

Addressing cyber threats or related risks in the post-pandemic era, where digital technology continues to dictate and alter daily proceedings, is crucial and of utmost importance to all concerns in higher education systems. It continues to raise significant concerns about the safety and security of the lives of students and educators, including unauthorized access to institutional information, records, intellectual property and, most worrisomely, the mental health implications of the dilemma. For reiteration purposes, threats are used in this review as an adverse use of digital technologies or communicable technologies in such a way that they inflict pain, injury, and damage on actors, records, intellectual property, and mental health [47, 70]. The threat also comes in the form of abuse, bullying, scamming, and unauthorized entry to access information without the owner's knowledge or consent [63, 62, 74]. Thus, identifying and analysing cyber threats in this paper review is essential for providing information, creating awareness, and offering guidance for higher education on recent but modern cyber threats that need an urgent address. Moreover, this review becomes imperative as a document that could be actively used if the current security challenges connected to the misuse of cyber-motivated technologies in society and higher education are to be considered. The review also becomes important to draw lessons that could prove important as added solutions to the current menace of cybersecurity divide in Nigerian society and the higher education system.

1.2 Objectives for the Review
The critical objectives considered in this review include the following:
1. Making sense of the world "cyber" and its relevance in today's digitally connected classrooms
2. Examining the nature of cyber threats in higher-education digitally connected classrooms.
3. Evaluating and discussing the various strategies to mitigate cyber threats in higher-education digitally connected classrooms.
4. Drawing insights from this review as lessons for the Nigerian higher education system and society

1.3 Importance of the Review
The use of digital technology in education, particularly in higher education, has significantly increased due to the impact of the COVID-19 pandemic [72]. However, interventions and shifts to digital technology during and after the COVID-19 pandemic, encouraged the use of communication between digital and interconnected computers using a medium in higher education sectors (otherwise known as cyber communications). Not only that but it raised critical concerns regarding the safety and security of educators' and students' identities, including institutions' official information [17, 21, 52]. Although educational institutions have embraced digital and cloud-oriented technologies for connected teaching, learning and administrative spaces, the associated risks or threats have become a pressing global concern, raising continuous debates among education stakeholders [17, 21], with the Nigerian higher education sector not left out [42].

In light of these challenges and ongoing debates, examining the cyber threats facing digitally connected higher education classrooms in these transitioning but uncertain periods is essential. This review examines the critical aspects of these cyber threats and their impacts on teaching and learning, explore possible solutions, and draw lessons applicable to higher education practices in Nigeria. By doing so, it seeks to equip students, educators, and education stakeholders in Nigeria with a deeper understanding of the multifaceted nature of cyber threats that could impact digitally connected classrooms in higher education.

Furthermore, the potential impact of this research on the Nigerian higher education system is significant, as it could help further raise or advance awareness of cyber threats in digitally connected classrooms in higher education, providing valuable insights for educators, policymakers, and researchers within the Nigerian higher education system. Therefore, the review presented in this chapter underscores the potential for enhancing the safety and security of digital connected learning spaces in higher education, highlighting the crucial role that each stakeholder plays in this process and fostering a sense of optimism about the future.

2. Review process

Published scientific articles from databases such as Google, Google Scholar, Mendeley, and the Directory of Open Access Journals (DOAJ) were used to gather knowledge on the subject matter under consideration. Not only that, but knowledge on the subject matter was also drawn from educational YouTube videos discussing and exemplifying incidences of cyber threats in education and society. In addition, specific keywords, such as cyber education, cybersecurity, cyber threats, and strategies for mitigating cyber threats in higher education, were instrumental in ensuring the relevance of the gathered literature. Additionally, the literature search was limited to articles published between 2020 and 2024, ensuring the currency and accuracy of this review. Moreover, the search was open to the literature within and outside Africa. In addition to focusing on the literature from 2020 to 2024, this review selectively incorporates academic reports and educational blogs and videos from 2020--2024. The selection of these reports and blogs was based on their relevance, credibility, and depth of their insights. Their incorporation was also essential for substantiating the review process and providing a comprehensive understanding of cyber threats to interconnected classrooms in higher education contexts. Additionally, incorporating reports, educational blogs, and scientific articles helps gather and present rich reviews by offering a deeper, more nuanced understanding of the different forms of cyber threats to interconnected classrooms and the different stop-gap solutions and advice recommended in the literature. To ensure the appropriateness of the studies, reports and educational blogs included, the author carefully examined the titles and abstracts of published articles or blogs, filtering out irrelevant and outdated articles that were unrelated or aligned with the study's objectives.

This review examines the diverse impacts of cyber threats in digitally interconnected classrooms. It commences by defining the significance of cyber threats in today's digitally linked classrooms, explores the characteristics of cyber threats in such settings, and examines strategies to alleviate the various cyber threats that impede the success of digitally connected classrooms in post pandemic higher education and society. The review presents valuable insights that can be implemented in instructional scenarios in Nigerian higher education, imparting lessons to prepare for emerging crises and establishing resilient digitally connected instructional classrooms and administrative practices suitable for the Nigerian higher education sector. It also stresses the importance of professional development for educators in higher education, reiterating the need for them to continuously gain understanding and awareness of the various risks associated with using digital technologies for connected lessons. Furthermore, it underscores the vital role of the government, education stakeholders, educators, and parents in collaborating to address the identified issues, highlighting the importance of joint efforts in tackling these challenges.

In the next section, the author discusses the phenomenon of cybers in today's digitally connected classrooms by succinctly examining the definition and importance of cyber and interconnected computers and completing the section with the advantages of cyber-connected computers in higher education instructional practices.

2.1 Cybers in contemporary digitally connected classrooms

The term "*cybers*" encompasses the exchange of information between digital and interconnected computers, typically over the internet [63, 51]. It involves a network through which computers, whether in the exact location or different locations, communicate and share resources to achieve specific objectives [51]. In higher education, digital, interconnected computers have led to the adoption of internet-enabled computers and open AI tools, which provide access to online databases and enable intelligence gathering over the internet [48]. Moreover, the adoption of cyber-oriented digital technologies such as internet-enabled computers, smartphones, interactive white boards, blackboards, and open AI tools, for instance, has facilitated unrestricted access to resources for innovative and flexible teaching and assessment methods, thereby connecting teaching and learning to global educational practices [55]. In Africa and elsewhere worldwide, higher education institutions have embraced the integration of cyber-oriented digital technologies that bring global perspectives into higher education practices to revolutionize teaching and learning engagements [4, 9]. The aforementioned cyber-oriented digital technologies not only enhance teaching methods and foster greater engagement among students and educators but also open up a world of possibilities for specific goal actualization and

skills development. Moreover, the rapid development of cyber inclinations and the integration of cyber-oriented digital technologies in higher educational practices has ushered in new teaching and learning approaches with the potential to extend learning experiences beyond traditional classroom settings and throughout students' and educators' lifetimes [4, 9]. Additionally, the rapid development of cyber inclinations and integration has resulted in global optimism for connected instructions and engagements in higher education.

Furthermore, the researcher added that the incorporation and inclinations of cybers in higher education-connected classrooms also promote digital citizenship, emphasizing the responsible, safe, and respectful use of internet-enabled digital resources by students and educators. This involves safeguarding and corrective use of information online, avoiding cyber threats or illegalities, and utilizing acquired information in a respectful, knowledgeable, and legal manner. Moreover, the presence of 'cybers' in digitally connected higher education classrooms is a catalyst for collaboration among students and educators. This collaboration fosters a sense of community and shared learning, as well as self-regulated learning. Self-regulation, as conceptualized by [18] in 1991 and [80] in 2001, aligns with the author's reasoning on the subject matter under investigation and involves the ethical use of digital technologies and software to promote mental stability and ethical technology use in higher education. It is a valuable skill that enables individuals, including learners and educators, to navigate specific learning pathways and use devices ethically with limited supervision. Ultimately, integrating 'cybers' in connected classrooms empowers students and educators to take ownership of the teaching and learning processes, facilitating self-directed learning and the acquisition of reusable skills. With respect to all of these possibilities, there are a myriad of threats in today's higher education-connected 'cybers' classrooms. These threats have different natures, which are discussed below.

2.2 Nature of cyber threats in digitally connected classrooms and higher education

Before the COVID-19 pandemic, cyber threats and associated risks were not widely acknowledged in higher education systems [24]. There was a limited emphasis on educating and raising awareness within academia and higher education-connected classrooms about the various natures and impacts of cyber threats. Today, sophisticated intelligent technologies for personal and general use are widely adopted, and their accessibility and diversity in the market are increasing [6, 69]. Intelligent technologies now offer unfettered access to information and resource acquisition for educators, students, and administrators in digitally connected higher education teaching and learning spaces [8]. However, the unethical use of these intelligent technologies has exacerbated cyber threats, significantly damaging intellectual property in higher education educational practices [11]. An example of the risks posed by using innovative technologies in higher education is the increased incidence of unauthorized access to and theft of resources and the promotion of predatory publications and designs that deceive scholars and students into investing their time and money in such projects.

The implications of these developments need to be thoroughly examined within the context of higher education. Although intelligent technologies facilitate the establishment of digitally connected classrooms, [25], [71] and [56] argue that their misuse for malicious purposes, such as hacking institutional and student bank accounts, individual or organisational information and identity theft to gain access to classified information, poses a significant threat. In higher education, personal intelligent technologies, whether connected to institutional devices or utilized in virtual environments, render the sector vulnerable. This vulnerability arises from students and educators being often permitted to bring and use their own devices and data bundles for learning and teaching purposes. As a result, students and educators are encouraged to use their devices in higher education. However, this practice has led to some students mastering the misuse of technology, making it difficult for central information management staff to identify critical vulnerabilities in the institution's network. The offensive students tamper with security configurations and access communal resources, further complicating the security setup of the institution. Therefore, the concern here is further linked to privacy leakage in workplace networks, organisation, and individual information.

[57] argued that privacy concerns in higher education limit the trust-belief system, ultimately impacting the development of non-self-disclosure behaviours. Although [65] opined that AI-driven higher education transformation could help address privacy issues through predictive analytics, the author argues that higher education with productive interests in this era of post pandemic transformation needs to harness ethical considerations, potential biases, and concerns about faculty roles and pedagogical implications in ensuring fairness, transparency, and accountability in protecting students', educators' and institutions' data privacy and security.

In addition to discussing the nature of cyber threats in digitally connected teaching and learning spaces, other forms of cyber threats in higher education instructional practices and society are discussed below:

2.2.1 Ransomware

In addition, the higher education sector faces other cyber threats, with ransomware being a significant risk. Ransomware involves the use of malicious software to encrypt data or computer systems, with the threat of blocking access or

publishing the data unless a ransom is paid [17, 62, 74]. [71] argued that higher education institutions are especially vulnerable to these attacks because of diverse network services, which are accessible via public internet protocol (IP) addresses. As a result, attackers view these institutions' IPs as attractive targets and tamper with them to redirect communications to gain access to the data or information of both the institution and its users. In addition, [22] opined that privacy concerns and data breaches are significant issues that affect various sectors, including higher education. Higher institutions and other sectors, according to [22], store sensitive personal, financial, and research data, making them potential targets for malicious actors seeking to exploit vulnerabilities in their information systems. The consequences of such attacks, as reasoned by the researcher and in line with [58] considerations on the impacts of cyber threats to institutional settings, can be severe, leading to financial losses, damage to reputation, legal consequences, and disruptions to academic and administrative functions. Importantly, these disruptions impact students, faculty, and staff, underscoring the human cost of cyberattacks.

2.2.2 Cyber Spoofing

In addition to discussing the nature of cyberattacks in higher education and the use of connected classrooms, another form is cyber spoofing. Cyber spoofing is a particularly deceptive form of attack. Cyber spoofing involves an unknown individual or entity masquerading as someone familiar with gaining access to sensitive information, financial resources, or personal data [68]. The imposters pose as trusted colleagues, reputable sources, or known contacts to deceive their targets [20]. In higher education context, cyber spoofing often takes the form of enticing invitations or offers, such as invitations to academic conferences, online lectures, opportunities for book publishing, free access to online resources, or the chance to publish in journals. Unfortunately, many educators and students have fallen victim to these deceptive tactics, often by clicking on seemingly illegitimate emails that promise career advancement or academic opportunities [3, 37]. This fraudulent activity is made possible by the harvesting of information from publicly available sources, including the abstracts of published articles [5, 50]. Cyber imposters then use this information to create convincing emails that appear to offer exciting prospects for students, academics, and professional growth [40]. Moreover, these deceptive emails typically end up as spam folders, and they often target individuals who are eager to expand their academic or research endeavours [77]. The author added that if recipients agree to participate or click on illegitimate links, their personal information is compromised, and they may become targets of ransomware attacks. Thus, the potential impact of cyber spoofing is significant, and it is essential for everyone in the higher education community and society to be vigilant and take proactive measures to protect themselves from these insidious threats.

2.2.3 Open AI-giarism

The widespread use of OpenAI tools, such as ChatGPT and other large language models, has made it easier for educators and students to access and generate responses via predetermined options within ChatGPT. However, it is essential to carefully consider the ethical implications of using these tools. Since machines have their own biases and cannot think and adapt as humans do, they provide fixed solutions to queries, regardless of the users' geographical locations, which can lead to open AI-giarism. In this review, "open AI-giarism" is described as the use of exact solutions, writings, or methods stored in a database in different educational contexts [19]. Using or reusing the exact solutions, writings, or methods in articles, theses, and dissertations in various contexts and locations, for instance, can be identified via similarity index checker software, raising concerns about new threats to higher education in the post-pandemic era, specifically plagiarism and relationships with the unethical use of cyber-oriented digital technologies. The potential for widespread use of open AI raises concerns about plagiarism among educators and students in this era of educational and social uncertainty. According to [56], the negative impact of AI on students and educators in this era of educational and social uncertainty includes the promotion of academic dishonesty and the hindrance of skill development.

Furthermore, [25] argued that open AI is now used for academic purposes, with some stakeholders (educators and students) not considering ethical implications. Additionally, an open AI tool such as ChatGPT can provide the same results, resources, outlines and contexts to students and educators in different countries without considering the implications for academic integrity, as it was previously loaded with predefined instructions. The author contend that the approach remains a threat to higher education connected classrooms, as it can lead to open AI-giarism. In support of this viewpoint, [23] suggested that known and unknown academic dishonesty in the use of open AI undermines trust in university educational practices. However, the research addresses the caveat that if academic dishonesty is caught through the conscious or unconscious use of open AI, such as ChatGPT, for academic purposes, the consequences are severe, as they can have lasting negative impacts on reputation.

2.2.4 Online Sex-Tortion

[2], in a video loaded on YouTube, relayed an experience of how an American student (male) was forced to pay part of the ransom online to the extent that Americans killed themselves with a live cartridge-loaded gun. Three Nigerian students bullied a certain American teenager online by disguising themselves as women to date the American boy and, through that, requested that he send his nude picture to Nigerians. Upon sending the nude picture, according to [2], "The American boy was asked to pay a ransom of 1000 dollars; otherwise, his nude pictures would be made public. The demand scared the boy and wanted to keep his privacy away from his parents and the public. Unfortunately, the boy only had 300 dollars to give them, scared to inform his parents. When the threat was too much online, the American boy sent

300 dollars and shot himself in the middle of the night in his room. The sound of the gun woke his parents in their room, only to find their dead son on the floor."

Although [2] reported the incidence in only the United States of America and Nigerian context, many similar cases might have been recorded in other parts of the world. The implications for the higher education sector and parents are that educators, especially school counsellors, need to occasionally educate new and old students on the dangers of visiting unsafe websites and avoid chatting or disclosing their information online to known or unknown persons. In addition, parents need to be remarkably close to the children (students) with lovely affect and interest in knowing what they are learning online, how they are solving school assignments online, how they are receiving lectures online and who they are interacting with online. However, the conflicts are that a majority of higher education students spend more time using digital technology for entertainment purposes even when they are attending lectures, whether online in the classroom or online at home. The act, according to [34], [41], [27] and the researcher's reasoning, leaves students vulnerable when they visit uncensored or unsafe websites and become psychologically demotivated and disinterested to socially interact and participate in learning activities, with the culprit of sextortion assassinating or committing suicide in the process.

3. Mechanisms to mitigate cyber threats in post pandemic higher education and society

On the basis of the above arguments, researchers have identified various methods to reduce or potentially eliminate cyber threats in digitally connected classrooms and society in post pandemic higher education. The researcher suggested that the institution's IT department and IT staff should consider implementing solid firewalls on its network computers. By activating firewalls, unauthorized access from within or outside the institution can be detected and blocked. Additionally, the researcher believes that the institution's IT staff should conduct regular security audits on all computers connected to the institution's network and ensure that passwords for students, educators, and administrators are changed regularly. Similarly, awareness programs on the advantages and challenges of cyber usage in institutions should be considered to educate the community about current or modern cyber threats in higher education and society.

Furthermore, the researcher added that cybersecurity education should be incorporated into the teaching curriculum at all levels of education in any country to mitigate cyber threats such as ransomware, spoofing, and privacy breaches. The researcher considers it essential to emphasize that the enactment of cybersecurity education is now imperative and needs to be urgently addressed by all education stakeholders. This education can be in the form of ongoing training, community-based awareness programs, and instruction on the various types of cyber threats that pose challenges to human and national development. In addition to these measures, parental involvement is crucial in educating students about the dangers of cyber threats in society and higher education. Most importantly, the researcher suggested that videos and images of victims and instances of cyber threats should be shown to students at home or in their schools to fully educate them about the dangers of cyber threats in today's post pandemic higher education and society.

To conclude, in the discussion of methods to mitigate cyber threats in post pandemic digitally connected classrooms, institutional stakeholders should conduct various workshops with educators and offer advice, education, and examples of the consequences of the unethical use of technology that supports cyber threats, as well as the dangers of unauthorized access to personal, institutional, and confidential information. For example, workshops could focus on strategies and activities to address the use of plagiarism detection tools and the integration of AI into teaching practices. It could also focus on ways to identify safe websites online, including recognizing spoof emails and methods of handling ransom demands. However, if these measures are overlooked in today's higher education practices, which are characterized by a high influx of technology and constantly changing dynamics of online information access [4], educators and their students may continue to be susceptible to academic dishonesty, be vulnerable to ransomware, and waste effort and resources in predatory conferences and journals.

In the next section, methodological implications in the form of learnable lessons for the Nigerian higher education system and society are discussed:

4. Learnable lessons for methodological implementations in the Nigerian higher education system and society

Having reviewed the concept of cyber threats in digitally connected classrooms in this era of post pandemic educational practices, it is critical to draw up insights from the review as learnable and reusable insights for methodological implementation in the Nigerian higher education system. Today, Nigerian society is facing massive cyber challenges, with their tentacles quickly spreading into the higher education system [15, 32, 79]. According to [29], [21], [31], [44] and [30], cyberbully, online fraud, racial abuse, pornography, data breaches, internet fraud, spoofing, and cyber threats imposed through the unethical use of open AI tools affect the Nigerian higher education sector, culminating in poor reading habits and disinterest in classroom participation. In addition, with the current technology expansion and adoption in Nigerian universities and society, the expansion, according to [43], will continue to precipitate cybercrimes, cause more havoc to education, call for redress and address the current education and security concerns caused by cyber threats. In support of [43]'s [43] argument [60], but with a caveat suggesting a possible way out such that hardware, software and infrastructure grant access to the operation and identity of educators, students and administrators must be secured loaded

on the institution work network, and the data contained therein should be reinforced to reduce incidents of unauthorized breaches or access. In addition, some of the previously discussed types of cyber threats identified by [62], [23], [68], [2] and [57] include breaching of privacy, spoofing, ransomware, sextortion and open AI-giarism, resonate with those mentioned by [28], [31], [44], [5], [15] and [30] ideologies on the forms of cyber threats in the Nigerian higher education system and society.

However, to achieve [43]'s, [60]'s and [79]'s propositions on the subject matter, the researcher draws important lessons from the review that the Nigerian higher education system could adopt to expand awareness of cyber threats and various forms and mechanisms to curtail the menace in education and society:

1. Effective communication and clear expectations are crucial in digitally connected classrooms. Communication between educators and students is needed to discourage engaging in cyber fraud among students. Additionally, educators must provide transparent guidelines for assignments and examination assessments. By communicating with students, educators may reduce confusion, encourage engagement, and ensure that students comprehend what is required of them [45, 67].

2. The incorporation of cyber education in the higher education curriculum is now needed in all departments, as students who perpetuate cyber fraud may not be limited to a particular department in the Nigerian higher education system [16, 28].

3. Collaborative activities among institution and student leaders and parents to increase awareness of cyber education in Nigeria [6]

4. Educators must investigate, reinvestigate, and confirm with colleagues before accepting online requests

5. Parents need to show more love and responsivities in working with their children to avoid engaging in cyber fraud, as some students in the Nigerian education sector are more inclined to engage in ugly practices [1, 3].

6. Regular assessment and feedback practices for receiving timely and constructive feedback from students, educators and parents are essential for promoting awareness of the different forms and dangers of cyber threats in higher education [16, 79].

7. The government, higher education and student leaders need to consider engaging in community and social activities to discuss and exemplify cyber threats in education and society in both rural and urban settings in Nigeria. This will also help promote awareness of cybersecurity and possible dangers related to neglect or ignorance.

8. Continuous training for educators on cybersecurity and cyber threats is not just necessary; it is essential [14]. It will help educators stay updated and prepared to understand and adapt to constantly changing cyber disruptions, thereby ensuring the quality of training despite technology misuse in higher education and society.

9. Higher education stakeholders, educators and student representatives need to engage in continuous and critical debates on the significance and drawbacks of open AI tools in higher education instructional practices.

10. Providing comprehensive support services, including counselling services, is crucial for safeguarding the mental health of students and educators in this era of teaching and learning uncertainty. Counselling services must offer the necessary support to cope with the stress and challenges of cyber challenges by demonstrating a deep concern for educators' and students' mental uprightness.

11. IT personnel must play a critical role in securing institutional and students' online resources. Their efforts to activate firewalls to resist unauthorized access and restrict access to the internet for unsecured or uncensored websites on campuses are integral to the smooth functioning of the institution.

The thoughtful analysis and application of the insights mentioned could minimize the susceptibility to cyber threats in digitally interconnected classrooms in Nigeria's post pandemic higher education system and society.

5. Conclusion

The exploration of digital technology in higher education has led to significant progress in the use of digital tools for teaching and learning in digitally connected classrooms. However, the adoption and use of digital technology in digitally connected classrooms has also sparked concerns about cyber threats in teaching practices within higher education and society. This thorough review explores the different types, functions, and dangers of cyber threats in today's society and digitally connected classrooms in higher education. Additionally, the review examines methods for preventing cyber threats in digitally connected classrooms by offering strategies to decrease these risks in higher education settings and in society. The perspectives presented in this review can be utilized to increase awareness among higher education stakeholders in Nigeria and society. In conclusion, the researcher emphasised the importance of continuous engagements and conversations between higher education stakeholders, educators, students, community representatives, and parents concerning the various types, functions, and dangers of cyber threats in today's society and digitally connected classrooms in higher education. Neglecting to address these hazards in higher education and society may lead to severe

consequences, such as disruptions in education, exposure to confidential information, and damage to the reputation of educational institutions, students, and the community.

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AI- DRIVEN SURVEILLANCE SYSTEMS FOR PUBLIC SAFETY

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ABSTRACT

Artificial intelligence (AI) is reshaping public safety through advanced surveillance technologies. AI-driven surveillance systems use machine learning, computer vision, and real-time data processing to enhance monitoring and threat detection capabilities. These systems offer improvements over traditional methods by providing more accurate, immediate insights, detecting anomalies and predicting potential threats with great precision. This paper explores the evolution, implementation, and impacts of AI-based surveillance systems on public safety, and focuses on their advantages, challenges, and ethical considerations. Through case studies and technological analysis, the study aims to offer a comprehensive view of AI's influence on public safety and its broader implications for privacy and civil liberties.

KEYWORDS: Machine learning, computer vision, real-time data processing, threat detection, ethical considerations.

1 INTRODUCTION

Artificial intelligence (AI) adoption in surveillance represents a significant advancement in the field of public safety Doe. J. (2024)[1]. AI-driven surveillance systems for public safety enhances effectiveness while safeguarding privacy. Traditional surveillance techniques often have demerit in addressing the complexities of modern urban environments and evolving threats. AI-driven surveillance systems, which incorporate sophisticated algorithms, machine learning, and real-time data analysis, offer a more effective approach to monitoring and managing security issues. Haggerty, K. D and Ericson, R. V (2023)[2]. The surveillance assemblage Technology, power, and privacy systems employ technologies such as computer vision for facial recognition, anomaly detection, and predictive analytics to identify and respond to potential threats with increased accuracy. Extensive data analysis quickly allows for earlier detection and improved response strategies.

However, AI use in surveillance also introduces important ethical and practical issues, such as concerns about privacy, data protection, and potential misuse. Kesan, J. P., (2023)[3]. Balancing public safety and privacy in the era of AI surveillance will benefit and enhance security with the need to protect individual rights is crucial. This study will examine the technological advancements, practical applications, and critical discussions related to AI-driven surveillance systems and their impact on public safety and civil liberties. Artificial intelligence (AI) is making substantial strides across various sectors, including the public safety sector according to Patel, S. and Chiu, T. (2024)[4]. Ethical considerations in AI surveillance: A framework for public safety. AI integration onto surveillance systems is revolutionizing urban monitoring, aiming to enhance security and improve law enforcement efficiency. This article explores the development, benefits, challenges, and prospects of AI-powered surveillance technologies in public safety.

2 THE EVOLUTION OF AI-POWERED SURVEILLANCE

Surveillance technology has transitioned from its early days of basic video recording and manual oversight to advanced AI-powered systems. According to National Institute of Standards and Technology, (2023)[5]. Guidelines for AI and surveillance will ensure transparency and accountability. Binns, R. (2023)[6]. The role of AI in modern surveillance system benefits and challenges are initially rely on simple equipment and human operators, modern surveillance now employs cutting-edge AI algorithms and machine learning to analyze data in real-time, facilitating more proactive and predictive safety measures.

3 BENEFITS OF AI-POWERED SURVEILLANCE

1. Enhanced Detection Speed: AI systems can swiftly analyze video footage to detect unusual or suspicious activities, enabling quicker responses compared to traditional methods.

2. Predictive Analysis: By leveraging historical and real-time data, AI systems can anticipate potential threats or criminal activities, allowing for preemptive actions and more effective resource allocation.

3. Operational Efficiency: AI can automate numerous routine surveillance tasks, reducing the need for continuous human oversight. This efficiency enables security personnel to focus on more critical and strategic tasks.

4. Improved Evidence Handling: AI technologies, combined with high-resolution cameras, enhance the collection and analysis of evidence, which is essential for thorough investigations and legal proceedings.

4 CHALLENGES AND CONSIDERATIONS

1. Privacy Concerns: AI deployment in surveillance raises significant privacy issues, including the scope of data collection and the risk of misuse of personal information.

2. Bias and Fairness: AI systems may reflect and perpetuate biases found in their training data. Addressing these biases is crucial to avoid unfair practices and ensure equitable outcomes.

3. Security Threats: AI-powered surveillance systems are vulnerable to cyber-attacks and data breaches. Ensuring robust cybersecurity measures is essential to protect system integrity and user privacy.

4. Legal and Ethical Issues: The use of AI in surveillance presents complex legal and ethical challenges. Balancing the benefits of enhanced safety with the need to protect individual rights requires thoughtful policy development and transparency.

5 FUTURE OUTLOOKS

The future of AI-powered surveillance systems is promising, with advancements expected to further enhance their capabilities as stated by Ball, K. and Deibert, R. (2022)[7]. Surveillance technologies and public safety. Ongoing improvements in AI technology and data processing will likely offer additional benefits, according to (European Union Agency for Fundamental Rights 2023)[8]. AI and surveillance, balancing security with fundamental rights, addressing current challenges, such as reducing biases and protecting privacy, will be crucial for successful implementation. Collaboration among technology developers, policymakers, and the public will be essential in shaping the future of AI-powered surveillance. Striking a balance between utilizing technology for safety and safeguarding personal rights will be key to effective integration.

6 CONCLUSIONS

In summary, AI-powered surveillance systems represent a significant advancement in public safety. AI surveillance systems also offer considerable advantages in monitoring, prediction, and operational efficiency, but addressing related challenges is vital for their responsible use. As technology evolves, continued dialogue and regulation will be necessary to guide the ethical deployment of AI in surveillance.

7 SUGGESTIONS

For enhancing public safety through AI-driven surveillance systems, it is recommended that policymakers and technology developers focus on integrating robust privacy safeguards and transparency measures. Ensuring that these systems are designed with clear guidelines on data usage, access, and retention will help in addressing public concerns about privacy and civil liberties. Additionally, ongoing evaluations and updates of AI algorithms should be conducted to mitigate biases and improve system accuracy. Collaborating with civil rights organizations and involving community input in the development and deployment stages can also promote trust and effectiveness in these surveillance systems.

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The Effects of AI on Students & Teachers and Value to Classrooms and School Libraries

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ABSTRACT

Artificial Intelligence has gradually become more essential aspect of our daily lives, and it does, have the potential to transform the way we work, exchange ideas, and gain knowledge. Based on this, the paper seeks to examine its effects in education, as well as the challenges both teachers and students face while using the AI. Media Ecology theory was used to guide the study. Findings from the study revealed that AI has provided students with a more personalized and engaging learning experience in education, and also facilitate instructors to meet the students need. The paper however concludes that the incorporation of Artificial Intelligence into the classroom has the ability to revolutionize the way students gain knowledge and how educators train. And thus, recommends that; libraries should work intimately with artificial intelligence developers to guarantee that the statistics used for training algorithms is assorted and diplomatic to all library consumers.

Keywords: Artificial Intelligence, students, teachers, libraries, Library users. Classrooms

1.0 INTRODUCTION

Artificial Intelligence (AI) has made waves in diverse ways including industries and the educational sector (Linder, 2020, p.98). It has provided students with modified knowledge and teachers with influential tools to follow student improvement and become accustomed to their teaching methods (For example, AI-based learning platforms, like Chat GPT, have gained popularity due to their capacity to engage students in a conversational style, similar to that of a individual tutor).

One other latest trend we have seen is where technology has made many people wary of the results that the use of Artificial Intelligence in the classroom will be of great benefits (Chen and Liang, 2020).

Thus, AI been one of the most promising technologies will help libraries to computerize processes, provide individual services, and also improve the user knowledge, and at the same time provide the students with additional well-organized and successful ways of learning. (Panda and Chakravarty, 2021). This is very true of AI hence its application in learning is concerned with the potential unenthusiastic impact it might have on learners. A number of authorities have argued that AI-based learning platforms may perhaps hinder serious thoughts dexterity and decrease individual interface, which is an important part of education (Partridge and Piccoli, 2018). This negates to the research "*effects of AI in education*".

It should be noted however that incorporating Artificial Intelligence in education would permit instructors to hand off every assignment to Artificial Intelligent for grading so the teachers can spend more time with students individually and modify the curriculum to be more relevant for every group of students (Wu and Liang, 2019, p.146). A number of students just require a little small piece of assistance in certain Subjects. Therefore, operating with an AI instructor might aid students with either social or academic anxiety gain self-confidence needed to for academic pursuit. Thus, the advancement in digital technology would increase students' aptitude to become completely absorbed in a tutorial.

1.2   STATEMENT OF PROBLEM

Nowadays, libraries have become a storehouse of knowledge globally; where a lot of people from all walk of life especially students who usually come to study in other grow in knowledge. Today, education has gone beyond merely lodging books as well as offering calm learning sitting rooms. Libraries are tied to technology and are now at the front position of empowering consumer via evenhanded utilization of artificial intelligence. AI has made the life of instructors easier, by providing additional enlightening support. In as much AI tries to improve the standard of learning there are also some draw backs. However, pertinent question is; how realistic is it to say that AI has the potentials of influencing learning? This therefore means that, the broad objective of this research shall be to examine the effects of artificial intelligence (AI) on students and teachers and its value to classrooms and school libraries.

1.3   OBJECTIVE OF THE STUDY

1. To examine the extent to which Artificial Intelligence has gone to improve academic performance of students and teachers.
2. To identify the relevant of incorporating Artificial Intelligence into school libraries.
3. To explore the possible ways of connecting the students to AI in school.
4. To identify the Challenges of Incorporating AI into the Classroom.

1.4   SIGNIFICANCE OF THE STUDY

This study is significant in many ways:

First, the study will add to the increasing body of knowledge and a veritable source of document from which future researcher in the relevant field could draw background information (Wang and Daniel, 2022).

Secondary, various areas by which artificial intelligence (AI) have improved the academic performance on both students as well as teachers will be identified.

Finally, students of library and information technology will find this material useful when carrying out research of this nature.

1.5   DEFINITION OF KEY TERMS

Artificial Intelligence:
This is the imitation of human intelligence progression by means of machines, like computer systems with definite applications of professional system, normal language processing, and dialogue recognition as well as machine visualization. In this study therefore, AI is refers to a set of know-how which allow computers to perform a diverse functions, including that of having the ability to see, know and interpret spoken and verbal communication, evaluate data as well as make suggestions.

Student(s):
In this study student refers to any person who is studying at a university or other place of higher learning

Teachers:
In this study a teacher is a person who teaches or instructs, or helps students to acquire knowledge, competence or virtue, via the practice of teaching.

Library (ies)
A library refers to a structure or a space containing collections of books, publications, films and recorded music for academic purposes or research works by the public or members of an institution. In this study therefore, it refers to a place set apart to contain books, periodicals and other materials for comprehension.

Library users:
In this study, library users are people like researchers, academic staff, students as well as support services staff who make use the services offered by the library

Classrooms:
This refers to space within a structure where learning takes place. In this study therefore, classroom refers to an apartment that serves as venue for the process of teaching and learning within the school premises.

2.1   REVIEW OF RELATED WORKS

Many scholars wrote on effects of AI in education. However, the study adopts few to arrive at findings, for instance, Chen and Liang (2020) argue that "with the integration of Artificial Intelligence, libraries can collect and analyze vast amounts of data to customize services and improve user experiences; hence, "Libraries are entrusted with protecting the privacy of their users and making sure that their personal information remains confidential and protected because the integration of artificial intelligence allows libraries to collect and analyze vast amounts of data to customize services and improve user experiences." He believes that this data-driven strategy poses questions regarding the handling and storage of personal data. The report made several recommendations for resolving these issues, one of which was to give strong data security measures top priority. The danger of data breaches can be reduced by putting encryption techniques, safe storage systems, and frequent audits into place. Examining it from the perspective of targeted instruction is another way to see what it can accomplish.
We prefer to employ the well-known slogan "artificial intelligence" (AI) whenever the situation calls for it. One application of AI is personalizing learning, which aims to adapt instruction to each student's unique needs (Partridge and

Piccoli, 2018, P.175). By altering things like the pace at which they learn, the resources they use, the order in which they use them, the technologies they use, the quality of the resources, the way they are taught, and the learning materials they use, personalizing learning also enables each person to meet the goals that have been set. However, without it, significant customization might not be feasible.

Learners can get instruction at their own pace and at the time that works best for them when AI is used for personalized education. You may create content that matches each learner's objectives and prior achievements by using AI technology to forecast how people will acquire knowledge. Every student's education is becoming more individualized thanks in large part to artificial intelligence. Teachers can customize learning experiences to fit each student's unique requirements, interests, and method of learning by utilizing AI technologies.

The advantages of integrating AI into the educational system

Introducing Artificial Intelligence into the classroom offers the advantage of delivering personalized knowledge to students. By analyzing student data, AI algorithms can adjust to their individual learning styles, offering customized feedback and suggestions based on their specific needs and capabilities. This approach can effectively maintain student engagement and motivation, ultimately resulting in enhanced educational performance (Ferrell, 2021).

Incorporating AI into the classroom offers the additional benefit of enhancing students' comprehension of this fast-changing technology. Teachers can assist students in gaining a critical viewpoint on AI and equipping them for the advancements and possibilities of the digital era by including AI in the curriculum

The customization of learning through Artificial Intelligence involves adapting teaching methods to meet individual student needs, providing immediate feedback, and offering guidance. Chat bots like Chat GPT have the capability to engage students, answer their queries, and maintain their motivation. Additionally, AI has the ability to gather and evaluate data on student performance, enabling educators to make informed decisions about teaching methods and curriculum enhancements. Lastly, integrating AI into the classroom can help students develop crucial 21st-century skills, such as problem-solving, critical thinking, and teamwork. These skills are essential for success in the digital age and can be honed through hands-on experience with AI tools and applications. However, it's important to note that while AI can greatly contribute to the classroom, it can never replace individual teachers.

2.2 How Artificial Intelligence sustain Teaching

1) Through various platforms, AI has modernized learning, allowing teachers to connect with a larger number of students and enabling learning materials to make a more lasting impact on learners (Partridge and Piccoli, 2018).
2) Effective integration of AI in the classroom has the potential to ease and support the essential profession of teaching.
3) AI assists, complements, and reduces the stress on teachers. This implies that an advanced AI-enhanced learning platform (MLP) can streamline teachers' workflow by generating sequenced lesson plans, syllabi, reading lists, and rubrics in response to instructions, thereby relieving teachers of repetitive and time-consuming tasks.
4) The prevalence of technology in classrooms, equipped with computers, may have led administrators to view educational technology as a drain on resources. However, when teachers leverage AI, they find themselves more effective, with additional time to dedicate to higher-value tasks.
5) AI, along with data and analytics, can assess each individual's learning progress, adjust the pace of evaluative activities based on their performance, and recommend suitable next-step assignments.
6) AI sustains personalized learning experiences in a way that was previously unattainable. Unlike human teachers, who may have limited time and resources, ChatGPT can engage with learners individually, providing them with a customized learning experience tailored to their needs and interests.
7) AI can provide immediate feedback, which is crucial for effective learning. ChatGPT can swiftly identify areas where learners are struggling and offer them additional support to overcome these challenges. This immediate feedback can help learners stay motivated and engaged in their learning journey.
8) AI can also grant learners access to vast amounts of information that they may not have had access to otherwise. This can assist learners in expanding their knowledge base and discovering new information that may be beneficial in their academic or professional pursuits.
9) AI helps alleviate the workload of teachers or educators, freeing up their time to focus on other important tasks such as lesson planning, grading, and providing additional support to learners who may require more personalized attention.
10) Ultimately, the use of Artificial Intelligence has improved student-teacher relationships.

Therefore, the integration of Artificial Intelligence, also known as 'AI,' in education has enhanced learning outcomes and supported student achievement.

The Difficulties of Using AI in Education

Even though integrating AI into the classroom has many advantages, it's important to remember that there are drawbacks as well. These include bias and restrictions on individualized learning, among other things:

I. The difficulty of incorporating this technology into instruction. The requirement for technical expertise is one of the main obstacles because it may be difficult for educators who are not knowledgeable with AI to apply it.

II. The high price of AI tools and apps is another difficulty. Many colleges and universities lack the funding to buy and maintain the equipment needed to integrate AI into the classroom; as a result, they might have to look outside the institution for partnerships or outside funding.

III. This amazing technology has the potential to completely transform education, but there are still issues that need to be resolved. Among the difficulties are teacher fear of losing their jobs, bias in AI models, a lack of personalization, and the possibility of errors.

IV. Errors in AI responses or recommendations may affect the results of learning. Concerns have also been raised regarding AI replacing specific teachers. To guarantee that AI in knowledge acquisition improves outcomes and helps learners, it is imperative to address these issues. In order to minimize biases, enhance personalization, lower error rates, and make sure that AI enhances human teachers rather than replaces them, careful thought and ethical application of AI are required.

V. The possibility of lower motivation and engagement among students when interacting with a machine rather than a human is another drawback. One may feel alone or cut off from the learning process if there is no real-time response or interaction.

VI. Lastly, integrating AI into the classroom raises ethical questions as well. Concerns concerning AI's effects on employment, security, and privacy are growing as technology advances. As students experiment with this fascinating and quickly developing technology, teachers need to be aware of these worries and take steps to protect them (Partridge and Piccoli, 2018).

What are the strategies for addressing the difficulties of integrating AI into the educational setting?

Incorporating AI into the classroom can assist teachers in integrating technology into teaching methods more effectively, while also offering students a more personalized and interactive learning experience. Here are some important best practices to keep in mind:

1. Forming a partnership with a trustworthy AI provider is essential for the successful integration of AI into the classroom. This could involve collaborating with a technology company, a local university, or a non-profit organization that specializes in AI education. The appropriate partner can offer assistance, training, and advice to help teachers effectively integrate AI into their teaching methods.

2. Instead of attempting to incorporate AI throughout the entire curriculum, it is advisable for teachers to begin with small steps and gradually progress. This approach allows teachers to gain familiarity with the technology, build confidence, and refine their teaching techniques over time. For instance, teachers could start by integrating AI-powered educational games into their lessons or utilizing AI algorithms to provide personalized feedback to students on their assignments.

3. The integration of AI into the classroom presents an opportunity for students to cultivate a critical perspective on this technology and its impact on society. Teachers should empower students to think critically about the ethical implications of AI and consider the potential consequences of its widespread usage. This can help students become responsible and well-informed digital citizens who are equipped to navigate the challenges and opportunities of the digital age

Merits of AI in Libraries

ANO AI in libraries offers the advantage of optimizing and enhancing the retrieval of information (Linder, 2020). With a plethora of digital resources available, AI algorithms can effectively sort through this abundance of information to present users with personalized and relevant results. This not only saves time but also improves the user experience by enabling quick and efficient access to needed information.

Artificial intelligence's ability to analyze large datasets and make intelligent predictions has the potential to transform how libraries function and cater to their communities. By leveraging the power of AI, libraries can improve user experiences, customize services, and ensure equal access to information for everyone. Another crucial aspect of empowering library users is improving information discovery.

Through AI algorithms, libraries can suggest pertinent resources based on users' preferences, reading history, and interests. This personalized approach not only saves users time but also introduces them to a broader range of materials they may not have otherwise come across. By tailoring recommendations to individual needs, libraries can empower users to explore new subjects, expand their knowledge, and engage with diverse perspectives. In addition, this new advancement also aids libraries in tackling information overload and enhancing the efficiency of sorting and arranging resources. By being able to handle and classify large volumes of data, AI algorithms can assist librarians in simplifying their work processes, thus allowing them to allocate more time to engaging with users on a personal level and participating in community initiatives. It should be emphasized, however, that the potential of AI in libraries extends beyond just efficiency and convenience. Ethical considerations are crucial in ensuring that AI technologies are employed responsibly and in a way that promotes fairness and inclusivity

The integration of AI tools in information literacy initiatives with ethical considerations is essential for libraries to help users critically assess information and distinguish between reliable and unreliable sources. It is important for libraries to ensure that AI algorithms are transparent, unbiased, and ethical. Additionally, safeguarding user privacy and data protection is crucial, as AI systems depend on large amounts of personal information to provide personalized recommendations and responses.

The potential of AI is vast and could improve the information literacy of library users by utilizing AI tools and technologies. Libraries have the ability to provide personalized recommendations, instant support through chatbots, counter misinformation, and encourage critical thinking skills. It is crucial to maintain ethical standards and prioritize unbiased access to information for all users while addressing privacy and data security concerns in AI-powered library services as we embrace these advancements. AI-powered library services have the potential to improve accessibility, recommend personalized resources, and streamline operations. Nevertheless, as libraries adapts to these technologies, it becomes essential to strike a delicate equilibrium between privacy and data security apprehension.

In libraries, AI-powered recommendation systems have the potential to improve personalized services by analyzing user preferences and behavior. They can recommend books, articles, or other resources based on individual interests, promoting discovery and helping users explore new areas of interest. AI can also be used to provide immediate support to library users through effective assistants. Thus, AI algorithms can help libraries make data-driven decisions by analysing patterns and trends in consumer behaviour. This can include optimizing collection development strategies and identifying areas where additional resources or services may be needed

2.2 THEORETICAL FRAMEWORK

The relevant theory to this study is media ecology theory, because of its suitability to the topic under study.

Media Ecology Theory
Understanding the social effects of technology and communication is the goal of Media Ecology Theory (MET) (McLuhan, 1964). According to this theory, media directly influence and structure culture. Communication studies are largely the focus of media ecology, which is the study of how media and communication processes influence human perception, feeling, understanding, and value (West & Turner, 2017).

In 1964, Marshall McLuhan highlighted the influence of technologies like clocks, radios, television, movies, and games, emphasizing their significant impact on the culture of society. He observed that electronic media had brought about a revolution in society and that people had become heavily reliant on these communication technologies. McLuhan believed that it was nearly impossible to find a society untouched by electronic media.

As the world has evolved, its technology has advanced as well. From the first printed books to the internet, media has both shaped and been shaped by society. The principles of media put forward by MET - enhancement, obsolescence, retrieval, and reversal - demonstrate how technology influences communication throughout its development. MET revolves around the concept that society cannot avoid the influence of technology, and that technology will always play a central role in nearly all modern-day activities.
The influence of media power and technology on society is based on three assumptions:

• The mass media permeate every aspect of society.

• The media have the ability to shape our perceptions and organize our experiences.

• Finally, the mass media connect the world together

The theory's importance lies in the direct influence of the media on us, as they hold a dominant position in shaping our views of the world and have the capacity to connect people globally, just as they connect students, teachers, and libraries. Consequently, the media can unite individuals worldwide into a singular social, cultural, political, economic, and educational system (Waran, 2018). This results in our ability to instantly access information, thanks to artificial intelligence

3.0 METHODOLOGY

This study adopts survey research method that includes a variety of methods for gathering data and information from the population in order to draw conclusions. The rationale is that open-ended and closed-ended questions are frequently included in surveys. Closed-ended questions require a yes/no response or a choice on a Likert scale, which is the well-known 1 to 5 scale that asks respondents to rate how much they agree with a statement about how human computer interaction affects consumers. Since closed questions are excellent for statistical comparisons of various respondent groups, they were also included. Respondents to open-ended questions were requested to formulate their own answers. For the latter, a methodical coding technique is needed to organize the responses' content across.

4.0 FINDINGS

Findings from the study revealed that:

1. Bring into play Artificial Intelligence enhanced learning outcomes by providing students with more efficient and effective ways to learn.
2. Artificial Intelligence has helped in streamlining and enhancing information retrieval processes in libraries.
3. Artificial Intelligence has provided students with new personalized and engaging learning experience and has also helped most teachers to meet up with the student's demands.
4. With the aid of AI-enhanced modern learning platforms teachers can now connect with several students and as well, share course material in a more lasting way.
5. Artificial intelligence now condensed the workload of teachers and educators.
6. And that, the use of Artificial Intelligent has improved students – staff relationships.
7. Lastly, AI has assisted libraries in dealing with the overload information thus, improving the efficiency of cataloging and arranging resources.

5.0 CONCLUSION

Integrating artificial intelligence into the classroom and library offers a special chance for educators, students, and librarians. Since "AI" has the ability to offer students tailored and captivating learning experiences, it also holds great promise for enhancing information literacy in library users and assisting them in developing critical 21st-century abilities like critical thinking and problem-solving.

5.1 RECOMMENDATIONS

From the findings, the following recommendations are drown that:
1. Libraries should think about implementing AI techniques that protect privacy.
2. To the greatest extent feasible, libraries ought to collaborate closely with AI developers to guarantee that the data utilized to train algorithms is both representative and diverse of all library users.
3. AI should be incorporated into the academic curriculum of higher education institutions in order to help teachers develop a critical viewpoint on this technology and to better prepare students for the opportunities and challenges of the digital age.

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MEDIA REPORTS, MISCONCEPTION OF SAFETY AMONG SOUTHERN NIGERIANS AND THE REALITY IN THE NORTH EASTERN NIGERIA

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ABSTRACT

Media plays key role in shaping public opinion and influencing individual perception. It is considered the watchdog of society responsible for reflecting upon, and dissecting, the society's trending issues. Be it safety and security, social welfare, corruption, politics and the economy, *vis a vis* the policies that regulate the populace. The media sets agenda for societal discussion through its daily reports. This paper's aim is to examine the security situation in the North eastern Nigeria through recourse to media propaganda in the southern part of the country, the goal being to reassess what the southerners have taken for granted about the security and safety in the North eastern Nigeria. To achieve this, the study utilizes both primary and secondary data (interviews, print, broadcast and internet material), which is analyzed through the Agenda-Setting Theory lens. The finding of this study reveals that there has been misinformation regarding the security situation in North Eastern Nigeria; interviews conducted in the course of this study suggested that the misinformation affects the perception of people in the Southern Nigeria. They simply believe that northeast is a "no-go area," laced with bombs, bandits and kidnappers. However, this study dispels the perception that "No safety in North Eastern states," especially Adamawa State. Adamawa is populated with peace - loving and communally friendly people: very kind and accommodating to law-abiding indigenes and visitors alike, in the face of situational insecurity reports about the North East. At present, Adamawa is not a dangerous place to venture to, based on the picture of insecurity reports galvanized by both local and international media organizations in the past. As such, the paper concludes that insecurity in the northeastern Nigeria is being exaggerated by various media outlets, as not every inch of space in the North East is full of bombs, terrorists and kidnappers
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Keywords: Media reports, Perception, Misconception of safety, reality of safety in northeastern Nigeria

1. Introduction

Whatever is reported by either a local or global media organization could cause harmony or fear in the minds of people living in a society. That is why the media is referred to as the "Fourth Estate of the Realm" (Burke, 1797). Media is regarded as the fourth arm of a democracy, and considered as the most powerful one among the other three, namely; the executive, legislature and judiciary. Hence, there is a saying that 'the pen is mightier than the sword' as it has power to cause crises or revolution in any society through what it reports. For this reason, it is not surprising how the genesis of insecurity in the North Eastern states of Nigeria occasioned by the activities of Boko Haram has been affecting the perceptions of many people in the southern region of the country and global community about the danger involved in travelling to the region, over the years. This is based on the "Agenda Setting Theory" of the mass media traceable to its beginning as far as 1922, when Walter Lippmann expressed his concern on the vital role that mass media can do in influencing the setting of certain image on the public's mind (Lippmann, 1922). Lippmann posits how mass media can set a particular agenda which can influence the opinions of the public. But, he did not classify it as "Agenda Setting Theory" in his published book.

As time went by, after Lippmann's propounding that media set agenda for public discussion, the concept of "Agenda Setting Theory" became well known among communication scholars. Other notable researches that made the theory popular in media studies included the works of McCombs and Shaw (1972). The duo showcased their works on the ability of mass media influences on voters' opinion during a 1968 presidential campaign. It is on the foundation of the duo's research, that the mass media industry began to have knowledge about the percentage of members of the public who constantly referred to information provided by the media.

In this vein, Matsaganis and Payne (2005) say Agenda Setting Theory has greatly attracted scholarly interests of over 350 researches galvanized after McCombs and Shaw's findings since 1972. The genesis of these is no doubt from the grass root works of Lippmann (1922); Lazarsfeld, Berelson, and Gaudet (1948); Lazarsfeld and Merton (1964); Berelson, Lazarsfeld, and McPhee (1954); Cohen (1963); McCombs and Shaw (1972); Funkhouser (1973); and of course Cobb and Elder (1983). Till date the theory remains relevant in the fields of communication and sociology.

The Agenda Setting Theory which began as an explanation of how the mass media affects to change the pattern in political behavior during elections (Cohen, 1963), later inspired and led to the development of hundreds of explorations among media scholars on how the mass media primes and frames issues for their audiences. Not only limited to such, the discussion also covers on how the mass media colours a particular event for their media audiences (Matsaganis and Payne: 2005). Therefore, the mass media role in shaping the mindset of people living in the Southern part of Nigeria about the activities of Bokoharam, bandits and kidnappers from recent past years till date is worth highlighting at this point of the paper.

There are various media reports about how the North East insurgency began from the time Bokoharam became a somewhat global daily news by nearly all media houses in Nigeria and the entire world and became an issue of scholarly discussions over the years.

For instance, a book titled "Boko Haram: Islamism, politics, security and the state in Nigeria" published by IFRA-Nigeria, African Studies Centre (2021) gives insight about the genesis of Bokoharam and other criminal activities that have given the North Eastern region of Nigeria, a negative image of insecurity over the years. The book is focused on the first attempt to understand Boko Haram in a comprehensive and consistent way. It examines the early history of the sect and its transformation into a radical armed group. It analyzes the causes of the uprising against the Nigerian state and evaluates the consequences of the on-going conflict from a religious, social and political point of view.

Dunn (2018) article titled "The impact of the Boko Haram insurgency in Northeast Nigeria on childhood wasting: a double-difference study" throws light on the history of Bokoharam and its effects on Northeast folks with special focus on its adverse consequences on children. It also beams on other regions of the country where pockets of conflicts have been commonplace over the years in a subtheme, Nigeria and Boko Haram which says:

> Nigeria is Africa's most populous country and among its most diverse with over 400 ethnolinguistic groups. The country is affected by several conflicts based on overlapping ethnic, religious, political and regional divisions including over resources in the Niger Delta, Christian-Muslim divides in the middle of the country, and most recently, the rise of Islamist groups in the north, most importantly, Boko Haram. Boko Haram ('Western education is a sin') was founded around 2002 in Maiduguri, the capital of Borno state and largest city in Northeast Nigeria. At least at its inception, the main tenet among its followers was regime change in Nigeria as they believe democratic and secular rule is in contradiction to Shariah.

Historically, Dunn (2018) points that in July 2009, the Boko Haram uprising began in Bauchi and spread to other northern states, leaving hundreds of followers, Nigerian law enforcement officers, and civilians dead. The following year, attacks in the Northeast and other parts of the country including bombings, mass shootings, and executions began to rise.

In May 2013, the president declared a state of emergency in the states of Borno, Yobe, and Adamawa. For this study, these states are defined as "conflict affected" and are compared to Bauchi, Gombe, and Taraba (the "non-conflict states"). People in the non-conflict states have certainly been affected by the crisis, but the entire population of Borno, Yobe, and Adamawa states are considered directly impacted by the Boko Haram insurgency, and portrayed a timeline of violent deaths attributed to events involving Boko Haram, which serve as a proxy for the intensity of the conflict. The timeline also shows July 2009 as a hard date for the start of the crisis in its highest violent form.

In the same vein, Cambridge University Press (2020) article titled "Boko Haram, youth mobilization & jihadism" gives vivid insight into the history of Bokoharam and other criminal activities in the North East that has brought insecurity to innocent Nigerians living there. It points out that the terrorist group is not actually fighting for Islam but for selfish reasons. In its punctuation of the terrorists as an anti-Islam and anti – people's interests group, the Cambridge (2020) says:

> Better known under the nickname Boko Haram ('Western education is sacrilege'), the 'Sunni Community for the Propagation of the Prophet's Teachings and Jihad' (*Jama'atu Ahlis-Sunnah Lidda'awati Wal Jihad*) emerged as a sect in the Borno region of north-east Nigeria, bordering Niger,

Chad and Cameroon. In March 2015, one of the factions of the group paid allegiance to Daesh (ISIS) and decided to be called the Islamic State in West Africa (*Wilayat Gharb Ifriqiyah*). Some in the media have presented this insurgency as part of a global jihad or, in the Nigerian context, a clash of civilization between Muslims and Christians. But the reality on ground has been quite different. Muslims have been the main victims of the group for a simple demographic reason: they are a majority in the north-east of Nigeria and civilians bear the brunt of the conflict. In fact, Boko Haram has attacked both Muslims and Christians. If the group has sometimes targeted Christian minorities, it has mainly killed Muslims who rejected its doctrine or cooperated with the security forces.

From the foregoing, it clear that Bokoharam has killed more Muslims than other religious disciples while claiming to be fighting a jihad. It boils down to the fact that the terrorist group was only using religion as a cover to attack innocent folks, irrespective of the type of religions they have been practicing.

To protect the life and property of innocent citizens in the North East, based on the realization of this common terrorist threat, the folks fostered the sense of national unity that propelled both Muslims and Christians to stick together to protect themselves through cooperation with the military personnel assigned by the Nigerian government to tackle the terrorists to restore the rule of law to the region. Hence, at present, Boko Haram, or what remains of it, is very fragmented, and it is important to look beyond the sentiment of religious fanaticism to analyze properly the grass root dynamics that explain how the sect mobilized combatants. The group has gone through four principal phases of recruitment, mainly in the region of Borno: firstly, a period of Islamic preaching (*da'awah*) under Mohammed Yusuf between 2003 and 2009; then, a descent into terrorism under Abubakar Shekau from 2010; a transformation into a guerrilla movement after the declaration of emergency rule in North-East Nigeria in 2013; and finally a spatial expansion of attacks after the launch of an international coalition made up of Nigerian, Nigerien, Chadian and Cameroonian armies in 2015.

After the clear annihilation of the terrorist group leaders, a new dimension of insecurity began such as banditry and kidnapping in the North East. All these have been copiously reported by the media, which is the reason many Southerners are still bearing in mind over the years and sees the region as a danger zone which none of their loved ones should travel to, despite the evidence of relative peace that has returned to the North East, especially in Adamawa State.

2. Theoretical Framework

The theoretical framework adopted in this paper is Agenda – Setting Theory. The theory discusses about how the mass media influences in making a certain issue a public agenda. The public agenda is the main focus or prime issue which the members of the society or public are concern about. The term Agenda Setting Theory is first used by McCombs and Shaw (1972). This theory shows the relationship that exist between what the media put forward as an issue and the media audiences or the public's reaction or attributes to such issue (Littlejohn and Foss: 2009).

Moreover, the theory has inspired and developed hundreds of latter explorations on how the mass media primes and frames issues for their audiences. Not only limited to such, the discussion also covers on how the mass media colors a particular event for their media audiences (Matsaganis and Payne: 2005).

From the foregoing, the theory is related to how the Nigerian media has been reporting about insecurity that influences the discussion and perception of the country's southern region populace about the dangers posed by bandits in the North East and why it is unsafe to travel or venture to go there. Hence, many southern Nigerians think everywhere in the north is unsafe. But there is relative peace and safety in some northern states such as Adamawa, whose folks are very friendly and peaceful to a large extent.

3. Literature Review

Mellows and Holmes (2021) in a report titled "Boko Haram and Banditry: Northeast Nigeria's Deteriorating Security Situation," document that "on the evening of February 23, 2021, suspected Boko Haram militants fired rocket-propelled grenades (RPGs) at several densely populated areas of the city of Maiduguri, the capital of Borno State. Some 16 people were killed, including children playing in a playground, and nearly 60 were injured. This shocking cost to human life is becoming a frequent occurrence, bringing trauma and fear to a region that has endured varying levels of armed conflict since 2009. Over the last 12 years, the Boko Haram insurgency and the Nigerian government's military counter-response have killed tens of thousands of civilians, displaced millions, and led to a massive humanitarian crisis."

Furthermore, the article posits that while Boko Haram is considered Nigeria's biggest security threat, the group is not the only treat that citizens in the north face on a day-to-day basis. Another WASL member Dr Fatima Akilu, the Executive Director of Neem Foundation warns that other insurgent groups have started operating there "making an already complex situation dire". Furthermore, armed criminal groups, locally known as "bandits" are preying on populations in the northwest and increasingly in the country's northeast with vicious attacks on local communities including carjacking, highway robbery, kidnapping, rape, and murder. The 'bandits' employ dehumanizing practices– using men as "pillows", forcing them to lie beneath their wife, or other female relatives, during brutal gang rapes. In a video recording which the peace activist describes as "too raw" to be shown, bandits are heard saying to each other "you can have two wives, which do you want?", while selecting women to abduct from communities. The descriptions paint a picture of lawlessness; a region of ungoverned spaces where this extreme violence has become almost a daily occurrence.

Nonetheless, Iyorah (2023) in a report titled "Rivalry among Boko Haram's factions compounds violence in Northern Nigeria," published by Al Jazeera, talked about splintered groups of Boko Haram and the dangers they pose to innocent folks living in northern Nigeria. In the report, the media organization points out that in recent years, local authorities in northwest Nigeria have been raising the alarm about the operations of Ansaru, one of its former factions, alongside bandits in Kaduna, which sits as a connector between the region and central Nigeria.

However, according to Iyoha (2023), the group, Ansaru reappeared in 2019 as an Al-Qaeda franchise in Nigeria after years of being underground, absorbing former JAS fighters who fled the northeast due to offensives in the Lake Chad area by a multinational force comprising Cameroon, Chad, Niger and Nigeria.

Ansaru offered to protect vulnerable Muslim-majority communities like Damari from marauding bandits, a strategy analysts say was meant to garner support in their fight against the government. It worked, and Ansaru gained the people's trust but established a proto-state and instilled fear in residents.

In another development, Akinyetun (2021), write–up titled "Banditry in Nigeria: Insights from Situational Action and Situational Crime Prevention Theories," published by Accord, an online media platform talks about the activities of "Bandits" operating in the Northern part of the country, which further make many Southern Nigerian folks wonder whether there is any where safe to live in the North.

The article says: "Insecurity in Nigeria is a recurring phenomenon that threatens the well-being of its citizens. The multipronged occurrence constitutes a bane to development and leads to the proliferation of crime. As a multifaceted quandary, insecurity assumes varying dimensions in different geopolitical zones. The South West is plagued by a surge in cybercrime, armed robbery, kidnapping, domestic crime, extrajudicial killings, herder-farmer conflicts, ritual killings, and banditry. The South East is a haven for ritual killings, commercial crime, secessionist agitation, kidnapping, herder-farmer clashes, attacks by unknown gunmen, and banditry. The South-South remains threatened by militancy, kidnapping, and environmental agitation. The North East has been subject to a humanitarian crisis lasting over a decade and caused by the Boko Haram insurgency and the Islamic State in West Africa Province. Meanwhile, the North West is enmeshed in illegal mining, ethnoreligious killings, and banditry. It is, therefore, an axiom that insecurity in Nigeria has assumed a disproportionate geopolitical stance and that it has claimed thousands of lives and extensive damage and loss of property."

The article further says that, "Even though the incidence of banditry in Nigeria is beginning to attract scholarship, the theoretical expositions remain embryonic. This article fills the gap by offering explanations for the occurrence of banditry in Nigeria through Situational Action Theory (SAT). This is done bearing in mind that an understanding of the motivating factors of crime provides insights and potential solutions. Furthermore, the available literature largely fails to characterize the phenomenon adequately and tends to offer vague solutions. The article thus proposes practical solutions through the strategies of Situational Crime Prevention (SCP). The article presents an overview of banditry in Nigeria and SAT, as well as discussing mitigating the challenge of banditry through SCP."

In this vein, the document explains that the situational stance advanced theory by SAT rests on four major elements: the person (psychological make-up, experience, and so on), the setting (the environment an individual is exposed to), the situation (choices resulting from interaction with the setting), and action (the person's behavior). SAT explicates the notion that factors that induce crime are the same for all people, regardless of their age and criminal career stage. The theory argues that people's propensity to commit a crime is different, just as environments also vary. The setting an individual finds himself in, determines whether a crime will be committed or not. For example, an individual who struggles as a result of multidimensional poverty and finds himself in an environment without guardianship, but with certain escape options and resources, is likely to commit crime. Crime occurrence, therefore, is the interaction between an individual's crime propensity and the setting's criminogenic incentive. A person with a low crime propensity – due to

a strong moral rectitude and/or the presence of government authority – will be less susceptible to criminogenic incentives, while a person with a high crime propensity is less likely to resist crime inducement.

To buttress the fear associated with travelling to the North East and some other areas in the North prone to Boko Haram attacks and bandits' activities, an organization known as Foreign, Commonwealth and Development Office (FCDO) advises people against travelling to the North East and some states in Northern Nigeria as if everywhere in the region is a mine field.

4. Effects of Insecurity

Alemika (2015) in a paper titled "Prevalence, Pattern and Consequences of Insecurity in Nigerian Cities" points that "The relationship between, security, growth, poverty reduction and development has received significant attention from researchers, international development assistance agencies and national governments. The security-development nexus has largely been investigated within the context of civil war or intra/inter-state conflicts (Stewart 2004)." This is very true because humans need peace and security to plan positively and make good results. Without safety and security no society can prosper.

However, the insecurity encountered in Nigerian cities has arisen more from criminality, especially armed robbery and ethno-religious conflicts, often rooted in competition for the control of state power and economic resources. OECD (2007) states that insecurity constitutes barriers "to political, economic and social development". Further, as an OECD-DAC Report has argued, "security and development are linked. Insecurity, crime and violent conflicts are among the biggest obstacles to the achievement of the Millennium Development Goals; they also destroy development" (OECD 2007). The Report observed that security is important 'to the well-being of the poor' and 'supporting poor people's physical security is vital part of reducing poverty' (OECD 2007).

There is no doubt that conflicts have diverse effect on the economy, including poverty reduction. Among such effects are gross reduction in actively taking part in productive economic activities; wasting of human and material resources; diminishing in investment and use of scarce resources hitherto meant for social services and infrastructural development to conflict-mitigation (Stewart 2003, 2004).

5. The Negative and Positive uses of media (Broadcasting, Print and Internet)

Messanga and Tajeugueu (2021), points out the negative use of broadcasting by some journalists to cause crises in the society they operate in, by using propaganda. The two scholars posit that "Propaganda is the dissemination of information for the purpose of influencing the opinions of others. It is a control and compliance instrument used by the dominant group (Fitzmaurice, 2018; Malhan and Dewani, 2020; Sanz, 2018). RTLM relied on this strategy to encourage Hutu to believe in the threat represented by Tutsi. The words of the journalist Karamira, made on April 22, 1994, illustrate the concern to influence opinions. He emphasized the role played by the CDR militia in managing the conflict with the Tutsi rebel movement of the RPF." This points out the negative use of the media by some journalists who overhype some issues and cause fear and crisis among folks. This practice is not ideal for the objective use of the media. The original aim of the media (broadcasting and print) should be imbibed by professional journalists in the following subthemes, with the exception of using it to cause fear and disunity or insecurity in the society.

5.1 Broadcasting as a tool of murder

The role of public radio in the Rwandan genocide is a deeply disturbing and tragic aspect of the events that unfolded in 1994. Radio Télévision Libre des Mille Collines (RTLM) was a prominent radio station in Rwanda at the time, and it played a significant role in fueling hatred, inciting violence, and contributing to the mass killings during the genocide. Here's an overview of how public radio was used in the Rwandan genocide:

1. Propaganda and Hate Speech: RTLM, along with other media outlets, became platforms for spreading propaganda and disseminating hate speech against the Tutsi ethnic minority. RTLM hosts and guests used dehumanizing language, stereotypes, and false narratives to portray the Tutsis as enemies, calling for their elimination and promoting ethnic tensions.

2. Incitement to Violence: The radio broadcasts on RTLM actively encouraged the majority Hutu population to engage in violence against the Tutsis. The hosts and callers advocated for the killing of Tutsis, providing

explicit instructions, and broadcasting lists of targeted individuals. They labeled Tutsis as "cockroaches" and called for their complete extermination.

3. Mobilization and Coordination: The radio served as a powerful tool for mobilizing and coordinating the genocidal acts. It disseminated messages that called upon Hutu citizens to participate actively in the killings, providing locations, strategies, and even specific instructions on how to identify and murder Tutsis. The radio played a significant role in organizing roadblocks and other checkpoints where Tutsis were targeted.

4. Psychological Impact: The constant and pervasive hate speech broadcasted on public radio had a profound psychological impact on the population. It created an atmosphere of fear, suspicion, and hostility, leading to increased polarization and a breakdown of social cohesion. The messages on the radio further reinforced pre-existing prejudices and fueled the escalation of violence.

The devastating consequences of the role played by public radio in the Rwandan genocide cannot be overstated. The incitement to violence, hate speech, and propaganda broadcasted by RTLM contributed to the dehumanization and systematic targeting of Tutsis, resulting in the deaths of approximately 800,000 people in just 100 days.

It is important to note that the use of public radio as a tool for spreading hatred and inciting violence is not limited to the Rwandan genocide. Throughout history, similar instances have occurred in various parts of the world, emphasizing the critical need for responsible and ethical media practices, as well as the importance of media literacy and the promotion of tolerance and understanding.

5.2 Broadcasting as a tool of information

Radio played a crucial role in broadcasting the progress of the Second World War and served as a primary source of news and information for people around the world. Here are some key aspects highlighting the value of radio during this significant historical period:

1. **Timely and Direct Reporting**: Radio provided near-real-time updates on the progress of the war, enabling people to stay informed about the latest developments. Radio broadcasters reported on battles, military movements, and strategic decisions, providing a sense of immediacy that print media couldn't match. This direct reporting helped create a shared understanding of the war's progression among listeners.

2. **Mass Communication**: Radio is a mass medium that reached a vast audience, both domestically and internationally. Unlike other forms of media at the time, such as newspapers, which required literacy and access to printed materials, radio was accessible to a broader population. It became a unifying force by transmitting news and updates simultaneously to millions of people, fostering a sense of national and global community.

3. **Propaganda and Morale Boosting**: Radio serves as a powerful tool for propaganda during the war. Governments used radio broadcasts to shape public opinion, bolster morale, and rally support for their respective causes. National leaders and military figures delivered speeches over the radio to inspire their citizens and troops, emphasizing the importance of unity, sacrifice, and victory.

4. **War Correspondents**: Radio reporters, also known as war correspondents, played a crucial role in providing on-the-ground accounts of the war. These journalists often accompanied troops into battle zones and reported live from the front lines, bringing listeners vivid descriptions of the fighting, the conditions, and the human stories behind the war. Their firsthand reporting provided a deeper understanding of the realities of war to those listening at home.

5. **Censorship and Control**: Governments tightly controlled wartime broadcasting to manage the flow of information and maintain national security. Censorship was used to suppress sensitive military details, prevent the dissemination of harmful rumors, and maintain public morale. However, despite censorship, radio still served as a vital source of information, enabling people to gather news and form their own perspectives.

6. **Home-front Communication**: Radio played a vital role in connecting soldiers and their families during the Second World War era. Through radio broadcasts, families received messages from their loved ones serving in the military, fostering a sense of connection and emotional support. It also provided a means for governments to disseminate information about rationing, war bond drives, and other home-front activities.

7. **Resistance Broadcasting**: In occupied territories during the Second World War, radio was a tool of resistance against oppressive regimes. Underground radio stations, such as the BBC's European Service and Radio Free Europe, broadcasted news and messages of hope, encouraging resistance movements and fostering a sense of resistance and unity among those living under occupation.

Radio's ability to transmit news, provide firsthand accounts, and serve as a source of propaganda and morale-boosting made it an indispensable medium during the Second World War. Its accessibility, immediacy, and mass reach allowed people to stay informed, connected, and engaged with the events unfolding on the global stage.

5.3 Broadcasting as a tool of unity.

The Apollo 13 mission, which encountered a critical failure in 1970 while en route to the Moon, is a prime example of how radio played a significant role in uniting the world during a crisis. Here's an overview of the role of radio in the Apollo 13 event:

1. **Emergency Communication**: After an oxygen tank explosion jeopardized the lives of the astronauts aboard Apollo 13, radio communication became the primary means of relaying critical information between the spacecraft and mission control at NASA. The astronauts and mission control used radio transmissions to exchange essential updates, troubleshoot problems, and devise strategies to ensure the crew's safe return.

2. **Global Broadcasting**: Radio networks around the world covered the Apollo 13 mission extensively, broadcasting updates and live transmissions from NASA. This global coverage enabled people worldwide to follow the dramatic events as they unfolded, fostering a sense of shared concern and engagement. Listeners around the globe tuned in to their radios to stay informed about the astronauts' well-being and the progress of rescue efforts.

3. **Communication with Families**: Radio played a vital role in facilitating communication between the astronauts and their families during the crisis. Families of the crew members relied on radio broadcasts to receive updates on the status of their loved ones and to offer messages of support and encouragement. Radio became a medium of reassurance, providing a link between the astronauts in space and their worried families on Earth.

4. **Rallying Support and Unity**: The Apollo 13 incident captured the world's attention, and radio played a crucial role in rallying support and fostering a sense of unity among people globally. Through radio broadcasts, individuals expressed their solidarity with the crew, offered prayers, and shared messages of encouragement. This collective support transcended national boundaries, highlighting the shared human experience and our capacity for compassion during times of crisis.

5. **Problem-Solving Collaboration**: Radio communication facilitated collaboration and problem-solving efforts between NASA and various international space agencies, scientists, and engineers. Radio signals transmitted data and technical information, allowing experts from different countries to contribute their expertise and work together to devise solutions for the astronauts' safe return.

6. **Celebration of Success**: When the astronauts successfully returned to Earth, radio broadcasts spread the news of their safe arrival and celebrated the heroic efforts of the crew and the collective achievement of the mission. Radio networks conducted interviews, shared the crew's experiences, and provided a platform for the astronauts to share their stories with a global audience, creating a sense of triumph and unity.

The role of radio in the Apollo 13 event exemplified its ability to connect people, disseminate information, and foster a collective spirit during a critical moment in history. By bridging distances, facilitating communication, and broadcasting updates, radio played an essential part in uniting the world in concern, support, and ultimately celebration as the crew overcame immense challenges and returned safely home.

5.4 Broadcasting as a tool of entertainment

The radio play "War of the Worlds" holds a significant place in the history of broadcasting, known for its unique and controversial impact on the public. Originally aired on October 30, 1938, as an episode of "The Mercury Theatre on the Air," the radio adaptation of H.G. Wells' novel "War of the Worlds" was directed and narrated by Orson Welles.

The play presented a dramatized account of a Martian invasion, simulating news bulletins and breaking reports to create a sense of immediacy and realism. It employed a format that blurred the line between fiction and reality, causing panic and confusion among some listeners who mistook it for an actual news broadcast. Here are key aspects to consider:

1. **Realism and Panic**: "War of the Worlds" utilized a simulated news format, with frequent interruptions and urgent updates, to convey a sense of authenticity. Many listeners who tuned in late or missed the initial disclaimer identifying it as a work of fiction believed that the events described were genuine. Consequently, panic ensued, as people thought they were under attack by Martians, resulting in some reports of mass hysteria.

2. **Impact on Broadcasting**: The broadcast of "War of the Worlds" sparked significant public debate about the power and responsibility of the media. It highlighted the influence of radio as a mass medium capable of shaping public perception and causing emotional reactions. The incident prompted discussions on ethics in broadcasting, the need for accurate information, and the potential dangers of media manipulation.

3. **Cultural Significance**: The radio play became a cultural touchstone, symbolizing the potential consequences of misinformation and the blurring of fiction and reality in the media. It demonstrated the power of storytelling and the ability of radio to create immersive experiences that captivate and sometimes deceive audiences. "War of the Worlds" continues to be studied and discussed in media and communication courses, serving as a cautionary tale.

4. **Orson Welles' Legacy**: Orson Welles, the director and narrator of the radio play, gained widespread attention for his innovative and provocative storytelling approach. The broadcast catapulted him to national fame and later paved the way for his illustrious career in film and theater. Welles' use of audio techniques and the performance style of the radio play left a lasting impact on the medium.

5. **Media Regulation**: Following the "War of the Worlds" broadcast, the incident prompted discussions about the need for increased regulation and oversight of the broadcasting industry. Regulatory bodies sought to ensure that broadcasters maintained responsible practices, including disclaimers for fictional content and adherence to guidelines regarding the presentation of news.

While the panic and fear associated with "War of the Worlds" may have been exaggerated in some accounts, the radio play remains a pivotal moment in broadcasting history. It raised important questions about the boundaries of media influence, the balance between entertainment and responsible reporting, and the impact of emerging technologies on society. The legacy of "War of the Worlds" serves as a reminder of the power and responsibility associated with the dissemination of information through broadcast media.

Conclusion

In conclusion, media is undeniably a seminal part of modern civilization. The media plays integral role in shaping societies, influencing cultures, and connecting people on a global scale. The value of the media transcends physical boundaries and cultural divides. It also empowers individuals and communities by providing access to education, news, and diverse perspectives. However, this paper contextualized the negative side of the media, especially in Nigeria. Being that the media sets agenda for societal discussion through its daily reports in Nigeria, this study established that ill-conceived reports about the security situation in the North eastern Nigeria has caused people in the southern part of the country to believe that all states in the north east are not safe to travel to or reside in. Consequently, the study analyzed interview reports, print, broadcast and internet material about the security situation in the north eastern Nigeria, and its finding established that the propaganda about being unsafe is untrue. Most of the states in the north eastern Nigeria, including Adamawa, are safe over a noticeable period of immediate past years till date. In fact, Adamawa is a peaceful and safe place for all. As such, the paper concludes that insecurity in the north eastern Nigeria is being exaggerated by some media channels, as not every inch of space in the North East is full of bombs, terrorists and kidnappers.

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Analysis of Pragmatic Framing in Selected Online News Reports on Nigeria's 2023 Presidential Elections

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Abstract

This research investigates the framing of online news reports about the 2023 presidential elections results in Nigeria. With textual evidence, it examines how some Nigerian journalists produce language in the context of national elections and the implications for peace and security. It also contributes to the understanding of pragmatic techniques used by journalists in the global South as a resource guide for the use of English as a second language. The study employed Mey's (2016) and Searle's (1969) theories for analysis. The corpus of the study consists of excerpts from six online news publications. Textual analysis established characteristic use of language by the selected journalists, grounded on the premise that journalists are guided by principles such as truth, accuracy, and fairness in their practice. However, being embedded in the Nigerian society where ethnic and religious divisions are rife, these factors may influence their practice. As such, their reportage may be framed by preconceived notions of cultural, ethnic and religious loyalties. Specifically, texts were examined for unattributed point of views, opinions, and utterances outside the territory of information of the journalist. With salient language selections and choice of sources, the reporters frame news towards a particular stance on socio-political issues. Findings revealed journalistic use of language in the study to be reflective of pragmatic strategies such as formal terms of address signifying cultural deference, the use of honorifics such as traditional titles, reflects Nigerian traditional values, politeness, and courtesy, while metaphorical expressions represent elections as a competitive sport or warfare where victors emerge and losers are vanquished.

Keywords: Framing, pragmatic techniques, online news, Nigeria, journalist, elections

1.   Introduction

Human language is embedded with symbolic and conventional means, through which people transfer and exchange meaning and experiences. However, from the conception of an idea by a writer to the delivery of the text to a reader and eventual actualization of meaning, an intricate interplay of illocutory intentions, assumptions, presuppositions, and inferences often take place. A theory of framing provides the means to describe the power of a communicating text (Entman, 1993). It demonstrates the ways in which text influences human consciousness. In the case of news reports, with words, journalists convey information with the intended perlocutory effect of readers decoding meaning. However, the point of view, and worldviews of both the journalist and the reader may not always be mutually harmonized. This is especially significant because journalists may inadvertently perpetuate a dominant point of view, worldview or frame despite adhering to principles intended to safeguard against bias. Hence, messages communicated via media texts cannot be said to be completely neutral, without bias or covert intentions to influence readers or otherwise shape meaning.

With textual evidence, this article aims to demonstrate the means through which journalists frame or orient readers, to promote certain points of view or worldviews in the context of the Nigerian 2023 presidential elections. Truth, accuracy, fairness and transparency are often touted as principles which guide the conduct of journalists in reporting the news (Kovach & Rosenstiel, 2021). Ethics and codes notwithstanding, it is possible that the meanings conveyed by journalists are intentionally or inadvertently subverted by representations which colour the truth. According to Lakoff (2005) frames are made up of ideas evoked by language. Words evoke frames or ideas in the human mind. These frames are representations of worldviews and points of view. Framing is therefore the use of language to promote a particular worldview. As such, this article seeks to establish the means through which journalists frame news in an election in the context of the global South.

Nigeria with a population of over 200 million is Africa's most populous nation (World Bank, 2023). The country's youthful demographic with the median age pegged at 18.9 presents a huge human resource which could be as much an advantage as it could be a disadvantage in global geo-political relations.

Nigeria's history, as a former British colony, also bears great significance for the study of English as a second language. The British colonial policy of cultural assimilation led to the imposition of the English language as a national language for a country of over 525 indigenous languages and over 300 ethnicities (World Atlas, 2023). The legacy of British colonial rule is evident in the lingering cultural imperialism in a post-colonial, multi-ethnic, and multi-religious country. The English language still serves as a national language in the country. Hence a huge number of the citizens speak English as a second language while many more speak pidgin English as a means of communication. A linguistic study of the unique use of the English language in Nigeria offers valuable insights into contemporary use of language and the ideological ramifications in a post-colonial, global-south context. Ajayi and Ajayi (2014) investigated political texts and jingles of the 2015 governorship elections in Oyo state, Nigeria. Their study found that the language of politicians in the state is characterised by practs such as accusation, challenge, abuse, warning, persuasion, commendation and condemnation. While Aremu (2017) focused on a pragmatic analysis of the use of metaphors in presidential speeches. Using Mey's framework of pragmemes, he identified the metaphorical characterization of elections as battles, sports or journeys. Building on their extensive findings, this article adds to the body of knowledge about what pragmatic tools journalists use in framing news about elections in Nigeria and the implications for peaceful co-existence.

1.2 Research Questions

1. What are the pragmatic framing techniques used in selected online news reports on Nigeria's 2023 presidential elections?
2. How are pragmatic techniques used to frame reportage in the selected online news reports?
3. What is the contextual relevance of framing techniques in the selected online news reports?

1.3 Nigeria's Socio-political Context

The 2023 elections in Nigeria were expected to usher in a new democratic tenure at the expiration of Nigeria's President Muhammadu Buhari's eight-year run. The ruling All Progress Congress political party had elected Mr. Bola Ahmed Tinubu as its presidential flag bearer while the major opposition party, the People's Democratic Party, presented former Vice President Atiku Abubakar as its candidate.

A third force gaining ground was the Labour Party which had adopted Mr. Peter Obi as its candidate for the elections. Mr. Obi had defected from the PDP after initial meetings suggested he would not secure the party's ticket. Apparently, the Labour Party was gaining a lot of support from the youth; who had become weary of the ruling political class. Mr. Obi, the former governor of Anambra state (2007-2014), was considered by some to be representative of the youth at 61 years of age compared to 70-year-old Mr. Tinubu and 76-year-old Mr. Abubakar.

In the run up to the 2023 presidential elections in Nigeria, the country had experienced rising inflation, insecurity, and scarcity of Nigeria's legal tender; the Naira. A few months to the elections, the Central bank of Nigeria announced a redesign of the Naira. Speculations were rife that the new monetary policy would deter vote buying and financial inducement for election malpractice. However, citizens were also left without money for basic needs such as food. The socio-political context of Nigeria's 2023 elections was thus influenced by economic strife.

2. Theoretical Framework

Mey's (2016) pragmatics acts theory propounds that utterances consist of both socio-cultural activity and their textual realization. It explains how linguistic features of text can be analyzed based on textual markers such as inference (INF), reference (REF), metaphor (MPH), relevance (REL), voice (VCE), shared situational knowledge (SSK) and metapragmatic elements (M). The analysis of these features highlights what the journalist pragmatically communicates in writing an online news report. This study therefore combines the analysis of news reportage against the backdrop of the socio-cultural context of elections in Nigeria. Pragmatic acts (practs) contained in online news reports of Nigeria's 2023 presidential elections were examined for characteristic features. The emphasis is on characterizing a typical, pragmatic act as it is realized in a given situation, not on prescriptive rules for use of individual speech acts. The interactional situation in which interlocutors realize their aims is not restricted to spoken utterances but includes written text and all manner of nonverbal communication (pragmemes). It follows that the identification of pragmatic acts in online news reports on Nigeria's 2023 elections will be an exercise in analysing how journalists make use of language. The political and cultural conventions in Nigeria at the time of the 2023 elections will only apply to that particular era. Hence the pragmeme of online news reports on the 2023 elections is made up of practs unique to that period with the effect of cataloguing information.

Searle (1969) proposed a systematic explanation of how language functions not just as a means for description, but as a tool for performing various actions. He posits that all meaning is relative to unintentional background. A sentence only has truth-conditions relative to some assumed background. This background can never be made fully explicit, because it is determined by inadvertent traditions and actions. Searle favours meaning being dependent on communicative intentions. Searle (1969) therefore categorized performances in language as performatives. Performative are further divided into five classes:

1. Expressives which show the speakers emotional or psychological state
2. Directives which include commands, orders, and requests
3. Commissives which include promises or commitment,
4. Assertives which show the speakers' alignment with the truth condition of the proposition
5. Declaratives which exert a change in the world such as pronouncements

3.0 Method

This qualitative study analysed the textual content of news reports from selected news websites. The study was designed as a corpus-based analysis of the online news reports based on availability and accessibility of media texts as sources of language data. The corpus of the study consists of news reports from six online newspapers and news websites. Google Trends was used to find out which newspapers ranked highest in search queries for online news reports on the day Nigeria's presidential elections were announced. A search query for news reports on the day the Nigeria elections results were announced (March 1st 2023), returned Daily Trust, Punch, Premium Times, and Leadership Newspaper articles online. The researcher also purposively selected the BBC and CNN news reports to account for foreign news coverage of the elections. The sample size of six news websites based on their readership and coverage of Nigeria were chosen to achieve a researchable limit within the ambit of the researcher's manual ability and time constraints. Data analysis was done manually without the aid of software word mapping. This analysis made use of Mey's (2016) model for pragmatic analysis and Searle's (1969) classification of performatives. Qualitative categories of pragmatic features of journalistic reporting emerged from the text analyzed. Analysis progressed from textual analysis to an interpretation of the meaning of text within particular contexts and then to the final stage of analysis of social practices concerning the wider society. The analysis covered three focal points. First the linguistic structure of the news reports was examined to establish framing through the journalists' use of pragmatic acts (practs).

The second outlines pragmatic acts within linguistic expressions guided by Searle's (1969) performatives theory. The third focal point explores how these utterances connect to the context of Nigeria's 2023 presidential elections.

4.0 Data Presentation & Analysis

Punch Newspaper

Excerpts 1 to 5 were all extracted from the *Punch* newspaper (**March 2023,** https://punchng.com/inec-declares-tinubu-winner-of-presidential-election/).

The excerpts are from March 1st 2023, the day the Nigeria 2023 presidential elections were announced by the Independent National Electoral Commission (INEC).

Excerpt 1 Punch Newspaper (March 2023, https://punchng.com/inec-declares-tinubu-winner-of-presidential-election/)
The Independent National Electoral Commission has declared the All Progressives Congress presidential candidate, Bola Tinubu, as the president-elect. Tinubu, a former Lagos State governor, was declared the president-elect after the 70-year-old polled 8,794,726 votes to win the 2023 presidential election.

Pragmatic Analysis

The reference (REF) to Tinubu's political affiliation in "*All Progressives Congress presidential candidate, Bola Tinubu*".

Is a pract which calls attention to party loyalty. Against the context of the political landscape in Nigeria, the group dynamics of the All Progressives Congress versus the People's Democratic Party and the Labour Party is foregrounded here. This appeals to feelings of identity politics. The frame positions supporters of the APC as victorious while supporters of other parties are left defeated. The metaphor (M) of identity is highlighted. The reference (REF) to APC evokes values and beliefs associated with the party. For opponents this may arouse feelings of ethnic and religious

marginalization especially as the candidates for the APC represent the Northern and South-western regions of Nigeria. The presidential candidate of the APC and his vice-presidential candidate are both Muslims. In the run up to the elections, this religious divide was a contested issue. The situational knowledge (SSK) of the religious and ethnic context of Nigeria's politics is also implicated here. The practs of the excerpt can be said to be group identification and a call to political loyalty.

The referencing (REF) of Tinubu as the APC's candidate evokes emotions of "us" versus "them" group dynamics. Readers may draw form the shared situational knowledge (SSK) of Nigeria's ethnic and religious divisions to interpret the pragmatic import and framing of the excerpt as divisive.

Excerpt 2 Punch Newspaper (March 2023, https://punchng.com/inec-declares-tinubu-winner-of-presidential-election/)

The three leading presidential candidates won in 12 states each while <u>Kwankwaso claimed only Kano State. Tinubu edged Atiku,</u> a former vice president and his closest challenger, with no fewer than 1.8 million votes. <u>The PUNCH reports</u> that the <u>2023 presidential election is the first time that Tinubu contested for the nation's top job.</u>
The former senator left office as a two-term governor of Lagos State in 2007 and is <u>credited with leading the coalition that ousted the PDP from power</u> in 2015 and has extended his influence beyond the South-West region in recent years.

Pragmatic Analysis

Excerpt 2 characterises the elections as a competitive race. The phrase "*The three leading candidates won while kwankwaso only claimed Kano state*" again evokes the metaphorical frame (MPH) of identity politics and party loyalty. The journalist could have just written "*the three candidates*" and identified them by name. However, the pract of choosing to use the adjective "*leading*" to modify the noun candidates, frames the candidates as superior to Kwankwaso. The use of the adverb "*only*" is also a pract which modifies Kwankwaso's achievement limiting him as inferior in comparison to the other candidates. The lexical choice of the verbs "e*dged", "ousted",* and the noun *"challenger"* furthers the framing of elections as a fierce competitive race. The phrase *"The Punch reports"* is a metapragmatic element (M) which serves to distance the assertion from the reporter as his sole opinion. It attributes the information as being that of the newspaper's editorial board. The relevance (REL) of presenting the information that Tinubu won the elections at his first attempt, portrays Tinubu as a strategic and successful leader, and influential candidate. This evokes the metaphorical frame (MPH) of leadership being associated with Tinubu. This is furthered by the use of phrases such as "*leading the coalition"*, and "*extended his influence".*

The narrative structure of presenting a chronological progression of Tinubu's political career from senator to governor and now president, presents a storyline of logical progression and growth. This positive framing of Tinubu as a strategic and influential leader, may lead readers to the inference (INF) that he is a credible leader and his victory may be perceived as well-earned.

Excerpt 3 Punch Newspaper (March 2023, https://punchng.com/inec-declares-tinubu-winner-of-presidential-election/)

Aside from Tinubu; Obi; Atiku, and Kwankwaso, other candidates that gunned for the nation's oval office include Dumebi Kachikwu of the African Democratic Congress; Kola Abiola, People's Redemption Party; Omoyele Sowore, Africa Action Congress; Adewole Adebayo, Social Democratic Party; Malik Ado-Ibrahim, Young Progressive Party; Prof Christopher Imumulen, Accord Party; Prof Peter Umeadi, All Progressives Grand Alliance; and Yusuf Mamman Dan Talle, Allied Peoples Movement.

Pragmatic Analysis

Excerpt 3, frames the election as a competitive race against major candidates and minor ones. The use of the prepositional phrase, "*aside from*" is a textual marker which ranks the three major candidates as higher than the others. Listing the other candidates and their political parties without further information, re-enforces that they are less important and not worthy of further description. The use of the adverbial "*gunned"* is a metaphor (MPH) which invokes the frame

of the elections as a competitive warfare. This is starkly contrasted from the expected democratic process of elections being a fair process where the electorate chooses a leader.

Excerpt 4 Punch Newspaper (March 2023, https://punchng.com/inec-declares-tinubu-winner-of-presidential-election/)

A tally of the votes announced by electoral officials from the 36 states and the Federal Capital Territory, Tinubu, in Borno, polled 252,282 votes across the 27 local government areas and was declared the winner by the state Collation Officer, Prof. Jude Rabo.Atiku and Obi could only garner 190,921 votes and 7,205, respectively while Kwankwaso amassed 4,626 votes.In Rivers State, Tinubu raked in 231,591 votes from 23 LGAs while the LP scored 175, 071 votes and the PDP polled 88, 468 votes.The Federal Capital Territory, however, proved to be a game changer for the Labour Party, which floored both Tinubu and his PDP counterpart.Obi's popularity in Abuja fetched him 281,717 votes while the former Lagos governor and the former VP shared the remaining slots of 90,902 votes and 74,149 respectively. Kwankwaso also polled 4,517 votes.

Pragmatic Analysis

Excerpt 4 establishes the credibility of the polls and Tinubu's emergence as president with factual data. The attribution of voting figures announced by an electoral officer establishes the information as factual. The phrase "*declared winner by*" is a metapragmatic act (M) which serves the purpose of hedging the journalist from accusation of presenting his own opinion about who won. In Nigeria, it is against the law and a treasonable offense for anyone other than an electoral officer or body to declare candidates as winners of elections. Thus, by clearly attributing the source of the election results, the journalist protects himself from the offense. The use of the phrase "*game changer*" reenforces the frame of elections as a competitive sport. This is again furthered by the lexical choice of *"floored*, and *"counterpart"*.
The use of the adjectival noun *"popularity"* to characterise Obi, is a pract which shows bias on the part of the journalist. An alternative lexical choice could have been to simply say Obi scored more votes in Abuja. That would have been a simple statement of fact without necessarily opining that his popularity effortlessly *"fetched"* him votes. When contrasted with Tinubu being characterised as *"raking"* votes and the other candidates *"sharing the remaining"* votes. The reader may infer (INF), that Obi was the only preferred, popular candidate while Tinubu was imposed.

Excerpt 5 Punch Newspaper (March 2023, https://punchng.com/inec-declares-tinubu-winner-of-presidential-election/)

"in some northern and middle belt states which included Zamfara, Kwara, Kogi, Benue and Kogi States. In Benue, the APC amassed 310,468 votes to relegate LP (308,372), PDP (130,081) and NNPP (4,740) to second, third and fourth places. As expected, Obi soared above other candidates in Plateau where he won by 466,272 votes compared to APC's 307,195; PDP's 243,808 while NNPP settled for 8,869 votes."

Pragmatic Analysis

Excerpt 5 continues the frame of elections as competitive sport.
The APC is negatively characterised as amassing votes. This lexical choice implies or connotes that the APC did not earn the votes but amassed them. Especially when compared to the lexical choice of Obi "*soaring"* "*as expected*" and winning. The metaphorical (MPH) characterization of Obi soaring again is starkly contrasted with the NNPP "*settling"* for less votes. The verb "*soar*" is a positive terminology which evokes imagery of a triumphant bird, flying high. The use of the passive voice (VCE) "as expected" without nominalization of who has the expectation of Obi winning is textual evidence of the journalist's bias. Without attribution, the reader is left to infer (INF) that this is the popular belief of the electorate. The excerpt is framed to portray Obi as a triumphant, soaring candidate, while the APC is characterised as greedy by amassing votes and the NNPP has no agency, only settling for whatever is left.

Leadership Newspaper

Excerpts 6 to 12 were all extracted from the *Leadership* newspaper (Leadership Newspaper (March 2023, https://leadership.ng/king-at-last-tinubus-long-journey-to-president/) on March 1ˢᵗ 2023 the day the Nigeria 2023 presidential elections were announced by the Independent National Electoral Commission, (INEC).

Excerpt 6 Leadership Newspaper (March 2023, https://leadership.ng/king-at-last-tinubus-long-journey-to-president/)

KING AT LAST!: Tinubu's Long Journey To President

* Lawyers squabble over state status of FCT APC candidate wins 25% in 30 states, scores 8.8m votes Mahama, Jonathan, others call for calm as PDP, LP kick

Pragmatic Analysis

Excerpt 6 is the headline of the news report. Journalistic writing is hinged on maximising informational content for the reader based on relevance. As such, the journalists and editors have made this specific linguistic choice of headline as a title which is foregrounded to capture reader's attention. In terms of performative function, this headline is an assertive. Assertives according to Searle's (1969) theory, are utterances which commit the speaker to the truth value of the proposition.

In this case, the journalist in making this choice of lexical selection asserts that Tinubu is indeed "*King*". The headline uses "*King*" as a metaphor which evokes a sense of monarchy. Just as Lakoff (2014) explained that media framing techniques include the use of metaphors to propagate a particular point of view. The metaphor "king" is starkly contrasted with Nigeria's democratic, federal republic system of government. The journalist's choice of headline potentially elicits inferences that Tinubu's emergence as president is more of a royal ascension than a popular vote election by the Nigerian people. It also conveys a sense of victory over the vanquished, thus positioning Tinubu as a dominant figure. The prepositional phrase "*at last*" also infers that it has been a long-term plan for Tinubu to be president. The use of the exclamation mark signals the pragmatic act of assertion, a sweeping emphatic statement. For the fact that the headline is not attributed to anyone else, the inference is that this is the voice of the reporter or the opinion of the *Leadership* editorial board. According to The Missouri Group (2014), editors are the gatekeepers who decide the newspaper's standpoint on key issues. Due to the gravity of election results, it is expected that this particular headline will not be published without proper vetting.

The use of the lexical item "*journey*' is a metaphor (MPH) which elicits the inference (INF) that Tinubus' emergence has been a long and perhaps painstaking process. A "*long journey*" in which readers may be oriented to sympathize with Tinubu's personal struggle culminating in a hard-won success. The relevance (REL) of the possessive apostrophe "s" in "*Tinubu's Long Journey*" is a pragmatic act (pract) which points to Tinubu's personal ambitions being framed as more important than the political event. This personalization also frames the informational content in such a way that Tinubu is foregrounded as being the focal point of the news story. The subheading offers more context by showing that there are contestations by lawyers over Tinubu's emergence as president. The lexical choice of the verb "*squabble*" is a pract which drwas the inference (INF) of a quarrel between the lawyers involved. This lexical choice pragmatically suggests a conflict among the lawyers which potentially delegitimizes Tinubu's emergence as president. Also, the call for calm by the former president of Ghana, John Mahama and Nigeria's former president, Goodluck Jonathan shows the gravity of the import of elections and that neighboring countries and international election observers are also vested in the conduct of elections in Nigeria. Former president Jonathan and Mahama are considered as important figures in African politics. As such the inclusion of their names in the headline may lead readers to the inference (INF) that heightened tensions may be imminent which necessitate their "*call for calm*".

The use of the lexical item "*kick*" is a pragmatic act which characterises the PDP and Labour Party as potentially hostile. The verb kick is an active form which can be interpreted as the opposition being belligerent and confrontational.

Excerpt 7 Leadership Newspaper (March 2023, https://leadership.ng/king-at-last-tinubus-long-journey-to-president/)

Presidential candidate of the All Progressives Congress (APC), <u>Asiwaju</u> Bola Ahmed Tinubu <u>has been declared winner of last Saturday's presidential election.</u>

Pragmatic Analysis

Jonasson (2001) defines focalization as a voice identification technique which answers the questions: *who speaks?* and *who sees?* This defines the narrative perspective or the point of view in a story. In this case the focal point of view (VCE), belongs to the journalist, Babafemi Badejo as indicated by the bye line underneath the headline. The underlined

statement is in the passive voice, deflecting agency away from the reporter. However, the lexical choice of not mentioning the Independent National Election Commission (INEC) as declaring Tinubu as winner of the election could be a specific omission in continuation of the *King* metaphor and the questioning of the legitimacy of Tinubu's presidency.

The use of the honorific term *Asiwaju,* a Yoruba traditional title in addressing the presidential candidate is a cultural convention of politeness especially amongst the Yoruba ethnic group to which Badejo belongs. This accounts for Shared Situational Knowledge (SSK) as posited by Mey (2016). Just as Irvine (1998) posits honorifics are a means of expressing respect, manifest in specially conventionalized forms. Honorifics signal deference in a way that requires a set of shared situational knowledge about the expression's significance and pragmatic potential. This indicates Badejo the journalist is pragmatically deferring to the personality of the APC candidate based on his shared cultural knowledge. In this excerpt the pragmatic act of honorific is established under the pragmeme of deference.

Excerpt 8 Leadership Newspaper (March 2023, https://leadership.ng/king-at-last-tinubus-long-journey-to-president/)

This development brought Tinubu into the limelight as he became a major arrowhead of the struggle to realise MKO's mandate. With MKO in jail, he fled into exile in 1994, becoming a leader cum financier of the National Democratic Coalition (NADECO), against General Sanni Abacha (GSA).

Pragmatic Analysis

The phrase "*this development brought Tinubu into the limelight'* is in the passive (VCE) which could be a choice by the journalist to obscure agency of Tinubu pushing for his own political ambition. The inference (INF) also frames his emergence in the political space as being the result of providence, fate or even divine destiny without expressly linking his emergence in the political sphere as being the result of Tinubu's own ambitions. The metaphor (MPH) of an arrowhead conjures an imagery of a warrior fighting for democracy. The (SSK) of MKO Abiola who is widely revered as sacrificing his life for Nigeria's democracy further places Tinubu on a pedestal as being a defender of Nigeria's hard-won democracy. In the transitivity analysis, the lexical choice of *fled* instead of travel, depart or left, conveys a sense of Tinubu cowering or running away from Nigeria. This is another marker for bias as the utterance's performative is expressive which means this is the journalist's attitude or feeling towards Tinubu's action of leaving the country. The verb *fled* also conjures a (MPH) of cowardice on the path of Tinubu.

Excerpt 9 Leadership Newspaper (March 2023, https://leadership.ng/king-at-last-tinubus-long-journey-to-president/)

GSA had pushed IBB aside, later dismissing after 84 days in office, the interim government of Ernest Shonekan that Babangida had put in place. Tinubu only returned to Nigeria in 1998 after the death of GSA. General Abdulsalami A. Abubakar (AAA) who took over wanted to quickly leave office and Tinubu was one of the beneficiaries of the General's call for Nigerians to canvass for offices.

Pragmatic Analysis

To fully understand the pragmatic acts in excerpt 9, readers have to draw inferences (INF) from Nigeria's political and historical context. Insights from the situational knowledge (SSK) of Nigeria's military regime relay the journalistic pragmatic intents. This period was characterised by political instability during the takeover of power by General Sani Abacha. References (REF) to key political figures such as General Sani Abacha, Ibrahim Babangida and Ernest Shonekan relay the turbulence of the period and the import of the news report. The relevance (REL) of specifying the '*84 days in office",* is a pract alluding to the transient nature and instability of power at the time.
This excerpt further expresses the (MPH) of cowardice associated with Tinubu's leaving Nigeria during the military regime. The prepositional phrase "*only returned"* is an expressive performative, another textual marker of the journalist's biased opinion. The journalist's lexical choices suggests a critique of the unstable transition of political power and Tinubu seemingly benefiting from the chaotic period. By stating that "*Tinubu was one of the beneficiaries*", the journalist implicates Tinubu as exploiting the political terrain for his personal gains. The (VCE) in the second underlined phrase is

in the passive, characterising Tinubu as lacking agency for his own political ambition. Describing Tinubu as a beneficiary of the largess of General Abdusalam Abubakar is a pract which characterizes Tinubu as subservient. The journalist relies on the (SSK) of the Nigeria audience privy to the knowledge of the era of military dictatorship to make (INF) that Tinubu was no match for the military ruler, that is why he fled and only returned to Nigeria when the military called for civilian actors.

Excerpt 10 Leadership Newspaper (March 2023, https://leadership.ng/king-at-last-tinubus-long-journey-to-president/)

He was involved in a struggle with the Federal government over Lagos State's right to create new Local Council Development Areas (LCDAs) to meet its large population's needs. The controversy led to the federal government seizing funds meant for local councils in the state in spite of the decision of the Supreme Court against Obasanjo, the President.

Pragmatic Analysis

The personification of the federal government as an entity with Tinubu struggling against it, is a continuation of the (MPH) of the warrior metaphor. Here Tinubu (REF) is characterized as one man struggling against the entire federal government for the benefit of his state with a large population. This frames Tinubu as an underdog fighting the cause of a large population. Readers are led to infer (INF) that Tinubu is a hero of democracy. The use of the passive (VCE) in the utterance "*he was involved in a struggle*" is a *pract* which frames Tinubu as being the victim not an instigator of the struggle. The use of the verb "involved" also obscures his level of complicity in the struggle. This utterance is an assertive which relays the journalist's commitment to the truth of the proposition. It means the journalist is presenting the information as factual. The presentation of (REL) information regarding the federal government's seizure of funds meant for Lagos state further leads readers to infer (INF) that Tinubu is a hero of democracy.

This is information that can be (INF) from the (SSK) of Nigeria's context of the administration of justice. Readers may draw from the (REL) information that the supreme court is Nigeria's highest court of justice and for Tinubu to win in that court, he is the protagonist while Obasanjo is characterized as the villain who flouts a supreme court order. For the Federal Government to have lost a Supreme Court case and still continue to punish Tinubu's state, portrays Obasanjo and the Federal Government as the villains (MPH).

Excerpt 11 Leadership Newspaper (March 2023, https://leadership.ng/king-at-last-tinubus-long-journey-to-president/)

Many people suggested that PMB did not want Tinubu as his successor in spite of the role the former Lagos governor

played in ensuring that he became President of Nigeria in 2015.

Pragmatic Analysis

Without an attribution to the source of the utterance, the voice (VCE) of the text can be alluded to as the opinion of the journalist. The use of the phrase "*inspite of the role of the former Lagos governor…*" Is a sentence adverbial which relays the (REL) of Tinubu's contributions to President Buhari's emergence. Nigerian readers may draw on the (SSK) to infer (INF) that Tinubu indeed believes that it is his turn to rule Nigeria. Again, this utterance evokes the imagery of the King (MPH) whereby people are installed in positions based on selection of the elite class and not necessarily because they are the choice of the people.

Excerpt 12 Leadership Newspaper (March 2023, https://leadership.ng/king-at-last-tinubus-long-journey-to-president/)

This message was read as meant for Tinubu, who was the frontrunner for his party's nomination. The body language of PMB, as he foisted a chairman on the party who in turn tried to foist Ahmed Lawan as the APC presidential candidate gave the impression that all was sealed against Tinubu. Against all odds, with the support of nine APC Governors from Northern Nigeria, the use of his war-chest, etc., Tinubu emerged as APC's presidential candidate.

Pragmatic Analysis

The first underlined utterance is in the passive (VCE). This pract obscures agency of who exactly interpreted the message as directed from president Buhari to his party's candidate, Tinubu.

Poulson (2023) posits that the use of passive constructions by news reporters is devised to insert unattributed information into a news story. With this pract not attributing the source of information, it suggests a bias or injection of the journalist's own views and opinion on the

subject matter. The utterance *frontrunner* is an (MPH) pract which elicits the comparison of an election to a race wherein the frontrunner is the winner of the competition. Hence the election is not thought of as a democratic process whereby the electorate choose their leader, rather it is described as a party race in which the fastest runner with the skills to beat competitors wins. In this scenario, Tinubu is also characterized as the candidate facing opposition from even within his own party. The (SSK) of Tinubu's wealth is inferenced (INF) to further depict Tinubu as the warrior who won because he had the most financial resources in his *war-chest*. The utterances make use of expressives as evidenced by the use of sentence adverbials *frontrunner and foisted* which relay the journalist's attitude towards the truth condition of the proposition according to Searle (1969).

Premium Times Online News Website

Excerpt 13 was extracted from the from *Premium Times* news website (March 2023, (https://www.premiumtimesng.com/2023-elections-presidential).

Mr Yakubu said a Certificate of Return for the President and Vice President will be presented by 3 p.m. on Wednesday at the National Collation Centre. Only the top four candidates won the presidential election in at least one state. Each of Messrs Tinubu, Atiku and Obi won in 12 states while Mr Kwankwaso won only in Kano.
However, winning a majority of states is not a requirement for a candidate to be declared the winner of the election.

Pragmatic Analysis

The journalist makes use of the formal markers in referring (REF) to the candidates and not calling them by name. This is pract of respect to portray the journalist's sense of professionalism and non-bias. *However* is a pract which highlights the clause and contrastive elements between winning states and the declaration by INEC. It serves as a metapragmatic element (M) in the utterance as a caveat to show that the number of states won is not the only requirement for winning elections in Nigeria. The journalist makes use of attributions as practs to distance the journalist from opinions that may be unfavorable, unpopular, sensitive, and to avoid culpability.

Verbs of utterance, and identifiers such as *he said*, demarcate the voice of sources of information. These attributions are metapragmatic elements (M) intended to give the news report credibility and to mark the news as objectively forming public opinion. The focus of narration is marked by the various political candidates who provide diverse points of views in line with the journalistic principle of balance and fairness. Expert sources and empirical data from the INEC lend credence to the report. The (VCE) narrative is in the present tense to convey a sense of urgency, timeliness and immediacy.

Daily Trust Online News Website

Excerpts 14 and 15 were extracted sequentially from the *Daily Trust* news website (March 2023, https://dailytrust.com/breaking-inec-declares-tinubu-president-elect/) .

Excerpt 14 *Daily Trust* news website (March 2023, https://dailytrust.com/breaking-inec-declares-tinubu-president-elect/) .
INEC Declares Tinubu President-Elect

The Independent National Electoral Commission (INEC) has declared Asiwaju Bola Tinubu of the All Progressives Congress (APC) President-elect. Prof Mahmood Yakubu, Chairman of the commission.

Pragmatic Analysis

The headline is short and straight to the point. This style of writing according to Pulson (2023) grabs reader's attention and improves clarity especially in online news reports due to the short attention span of readers in the digital age. The performative value is an assertive which is a pragmatic act that represents a state of affairs according to Searle (1969). Here the journalist tells the reader information that is deemed factual because the source of the information is the INEC which has the constitutional power in Nigeria (SSK) to declare a candidate president-elect. The (VCE) is in the active with the agency assigned to INEC and Tinubu the recipient of the action of declaration. The use of the honorific term

(REF) *Asiwaju is a* pract of formality which relays the neutrality and professionalism of the journalist. The (REF) serves to distance the journalist from the subject matter to show that the relationship is one of formality and as such the journalist is assumed to be not biased towards the subject.

Excerpt 15 *Daily Trust* **news website (March 2023, https://dailytrust.com/breaking-inec-declares-tinubu-president-elect/).**

The Independent National Electoral Commission (INEC) has declared Asiwaju Bola Tinubu of the All Progressives Congress (APC) President-elect. Prof Mahmood Yakubu, Chairman of the commission, pronounced Tinubu President-elect at <u>exactly 4:10am</u> on Wednesday<u>He said</u> Tinubu polled a total of 8,794,726 votes to defeat his Peoples Democratic Party (PDP) <u>rival</u>, Atiku Abubakar, who polled 6,984,520 votes while Peter Obi of Labour Party, secured 6,101,533, and Rabiu Kwankwaso of New Nigerian Peoples Party <u>trailed</u> with 1,496,687. <u>He said</u> valid votes were 24,025940 and rejected votes were 939,278, while the total votes cast were 24,966218. Declaring the final result, <u>the INEC Chairman said</u> Tinubu and the APC also satisfied the constitutional requirement.<u>Yakubu said</u> the certificate of return (CoR) would be issued to Tinubu and his <u>running mate</u>, <u>Senator</u> Kashim Shettima by 3pm on Wednesday

Pragmatic Analysis

The utterance *at exactly 4:10 am* is a pract which calls on the (SSK) of the socio-political context in Nigeria to highlight and lead readers to (INF) about the legitimacy of the declaration. The (REL) of including the exact time is that the announcement was made in the early hours of the morning when most Nigerians were asleep. Depending on which candidate the reader supports, the utterance may be interpreted as questioning the legitimacy of the announcement if it had to be made at night when most people were asleep to suppress violent reactions and protests or that it was announced at that time merely as a matter of it being a long meticulous process which took hours to complete. Verbs of utterance: *He said*, *The INEC Chairman said*, *Yakubu said*, are (REF) practs of credibility. The journalist's use of verbum descendi according to Mey (2016) serves to attribute the proper source of information. This gives the journalist credibility and relays the information as a transparent and factual account not just the journalist's personal opinions. The use of the formal title *senator* is a pract of formality and neutrality which relays that the journalist is setting a professional boundary between himself and the subject matter. If he were to call the vice president-elect by his first name, that may be interpreted as establishing a close informal relationship with the subject matter which could also be a marker for favoritism and bias in the news report. The performative of the utterances are assertive, depicting the journalist's commitment to the truth value of the propositions.

BBC Online News Website

Excerpts 16 to 20 were extracted from the *BBC* news website (March 2023, https://www.bbc.com/news/world-africa-64760226) from the online news report on March 1st 2023, the day the Nigeria 2023 presidential elections were announced by the Independent National Electoral Commission, (INEC).

Excerpt 16 *BBC* **news website (March 2023, https://www.bbc.com/news/world-africa-64760226).**

Bola Tinubu wins Nigeria's presidential election against Atiku Abubakar and Peter Obi
<u>*Ruling party candidate*</u> *Bola Tinubu* <u>*has been declared*</u> *the winner of Nigeria's* <u>*disputed*</u> *presidential election.*

Pragmatic Analysis

The excerpt is the headline of the story. The performative classification is the assertive which show the journalist's commitment to the truth value of the proposition. This presents the utterance as factual.
The sub-heading gives more information about the story. The (REF) *ruling party candidate* is a nominalization which relies on the (SSK) of readers being aware that the ruling party in Nigeria is the APC in order to (INF) that Tinubu has an advantage of the incumbent government especially as it relates to power transitions in Nigeria. Incumbent governments often have state resources and influence at their disposal which may give them an edge in elections. The use of the passive (VCE) *has been declared*, obscures agency of the INEC as the actor. This is perhaps an attempt to focalize the information as Tinubu's declaration not necessarily who made the declaration. Based on CNN's international outlook, the editorial decision might not necessarily be interested in the electoral umpire. The practice of electoral coverage in America is different from that of Nigeria. American news organizations are at liberty to announce the winner of elections based on their independent polling and voting data predictions. As such to an American audience the official electoral umpire might not be regarded as having a sacrosanct authority. In Nigeria however, only INEC has the constitutional

power to declare a winner. Anything contrary to that will be against the law. The adjectival *disputed* is a pract which signifies the bias of the journalist. Without attributing the information to a source or using quotation marks, the reader is led to an (INF) that this is the opinion of the journalist.

In analysing the (VCE), the journalist is the only identifiable voice because no other source has been attributed to the proposition. The (REL) of placing this pract at the top of the story also alludes to a framing or an attempt to orient the reader towards the worldview that the election is indeed popularly disputed.

Excerpt 17 *BBC* news website (March 2023, https://www.bbc.com/news/world-africa-64760226).

The 70-year-old veteran politician got 37% of the vote, official results show. His main rival Atiku Abubakar polled 29%, and Labour's Peter Obi 25%. He was nevertheless defeated in the city by Mr Obi, a relative newcomer who mobilised the support of many young people, especially in urban areas, shaking up the country's two-party system. Mr. Tinubu won most other states in his home region of the south-west, where he is known as a "political godfather" - for helping to put others into office. He campaigned for the presidency under the slogan: "Emi lo kan", which means "It's my turn" in Yoruba.

Pragmatic Analysis

The (REF) of the adjectival, *70 -year-old politician* is a pract which reflects the journalist's bias in qualifying Tinubu's age. Moreso as the age of the other contenders are not mentioned. In subsequent sentences, the Labour Party's Mr. Obi is framed as popular with young people. This elicits the (INF) that he is younger and more energetic. As such being a *newcomer* able to *shake up* the *country's two-party system* are all metaphors (MPH) for his vibrance and fresh appeal to young Nigerians unlike the *70-year-old political godfather*. The (REL) of foregrounding the information of Tinubu's defeat in his home state is another pract of bias. It shows the journalist's attempt to delegitimize Tinubu's win. After giving background information of Tinubu's campaign based on his track record of rebuilding Lagos when he was governor, presenting the information of his loss in the next sentence is cohesively linked to lead readers to the (INF) that Tinubu was unable to win his home state.

The (REL) of foregrounding this information is a pract to evoke the question of how Tinubu won the presidential election? In the instance that similar analysis of the other candidates' performances in their home states were not mentioned, the pract is a marker for bias. The Labour party's Peter Obi won mostly in the South-East and did not win core Northern states.
The PDP's Atiku Abubakar also won in majorly Northern states and did not win as many votes in the South-West. By omiting this key analysis, the journalist has pragmatically selected the opinions suitable to his narrative. The (REL) of including the slogan *Emi lokan* further frames Tinubu as a selfish politician who is focused on pursuing his own interests. The journalist also misrepresents the circumstances surrounding the emergence of the catch phrase *E mi lo kan*. The phrase emerged during a speech on the 3rd of June 2023 in Ogun state, while Mr. Tinubu was addressing members of his own party. In his speech to APC delegates ahead of the party's primaries, The Guardian newspaper quoted Tinubu as saying "It is my time, I am educated, I am experienced, I have been serving people for a long time. Bring me the presidency, it is my turn". Hence the BBC journalist's out of context quote is a pract which misrepresents the circumstances surrounding the pract *Emi lokan.*

Excerpt 18 *BBC* news website (March 2023, https://www.bbc.com/news/world-africa-64760226).

Scenes of celebration have been reported in Mr Tinubu's strongholds in the south-western states.
Traditional drummers lined the streets, beating their drums for excited dancers in Osun, while supporters marched to a live band in Ekiti. Some partied into the early hours in Lagos, even though he was defeated by Mr Obi in the city. The normally bustling streets of Lagos are relatively quiet on Wednesday, the usual rush-hour traffic has not been seen and some shops, businesses and banks have not opened.

Pragmatic Analysis

The (INF) from the underlined phrases is that the celebrations were limited to candidate Tinubu's strongholds alone. The first sentence is in the passive voice obscuring agency of who reported the scenes of celebration. This also shows the journalist's non-commitment to the truth of the proposition. This is achieved by distancing the source of the information from the journalist. The (REL) of the information that "*Some partied into the early hours in Lagos, even though he was defeated by Mr Obi in the city. The normally bustling streets of Lagos are relatively quiet on Wednesday*" Is to foreground the information that Tinubu lost his home state. Again, the journalist use of the adjectival, the *normally bustling street of Lagos* is another pract to portray the uncertainty that followed the announcement of Tinubu's victory in the presidential election.

Excerpt 19 *BBC* news website (March 2023, https://www.bbc.com/news/world-africa-64760226).

Life has returned to normal in places that did not support Mr Tinubu, like the capital, Abuja, and Kano in the north. In north-eastern Adamawa state, home to Mr Abubakar, there is an air of disappointment in the main city Yola, but grudging acceptance that after several attempts for the presidency, it is time for the former vice-president to move on.Mr Obi's stronghold in south-eastern Anambra state, where he once served as governor, is quiet but there is an underlying sense of bitter anger. Many feel frustrated at what they see as a fraudulent electoral process.
Pragmatic Analysis

The (INF) of the first underlined utterance is that life has become *abnormal* for the places that supported Tinubu during the elections. While in places that supported Tinubu, people have gone about their *normal* life. The journalist's (VCE) is apparent with the expressive performative: *there is an air of disappointment*. The underlined phrases are expressive performatives which relay the journalist's opinions especially as the utterances are not attributed to any other source. These are practs of the journalists' personal opinions because the opinions (VCE) are not attributed to any source and there are no textual markers like quotation marks or verbs of utterance to show whose voice it is other than the journalist's. Expressive performatives relay the writer's attitudes and belief about the propositional content of utterances.

Excerpt 20 *BBC* news website (March 2023, https://www.bbc.com/news/world-africa-64760226).

He will now have to prove that he can hit the ground running and that he is still the same formidable force who built modern Lagos, Nigeria's commercial hub.Mr Tinubu, known as "Jagaban" by supporters, will now be looking at unifying a country that is retreating into regional lines and religious blocs, as the election results show.While he met the 25% requirement in two-thirds of Nigeria's 36 states to show he was nationally accepted, the nature of the win indicates the absence of a truly national party. Mr Obi won in Christian-dominated states and former strongholds of the main opposition Peoples Democratic Party in the south, while the PDP support shrank back into its northern heartlands.

Pragmatic Analysis

The underlined utterance is the (VCE) of the journalist as it is not ascribed to anyone else. The journalist further ascribes judgement to the nature of Tinubu's win. This analysis is outside the journalistic intention of just relaying factual information. The journalist is not a political analyst nor an expert on Nigeria's national values for him to express his opinion on these matters is another pract of bias. The INEC only released the election results while the journalist has gone ahead to interpret the results based on his preconceived notion of regional lines and religious blocs. With the final paragraph of the news report ending on this note, the reader is left with the inference (INF) that Tinubu's presidency is not accepted by the majority of Nigerians. This is another attempt by the journalist to influence the reader with his own bias.

CNN

Excerpts 21 and 22 were extracted from the *CNN* news website (March 2023, https://edition.cnn.com/2023/02/28/africa/nigeria-presidential-election-result-intl-hnk/index.html) . on March 1st 2023, the day the Nigeria 2023 presidential elections were announced by the Independent National Electoral Commission, (INEC).

Excerpt 21 *CNN* news website (March 2023, https://edition.cnn.com/2023/02/28/africa/nigeria-presidential-election-result-intl-hnk/index.html)

A Nigerian opposition party has said it will launch a legal challenge after Bola Ahmed Tinubu was on Wednesday declared the winner of Nigeria's controversial presidential elections*. Tinubu, 70, represents the ruling All Progressives Congress party, which received close to 8.8 million votes – about 36.6% of the total, according to Independent National Electoral Commission (INEC) chairman Mahmood Yakubu.."We won this election as Labour Party, we are going to claim our mandate as Labour Party," said Datti-Baba Ahmad, the party's Vice Presidential candidate.*

Pragmatic Analysis

The information about the opposition's rejection and legal challenge is foregrounded over Tinubu's emergence as winner of the elections.

The relevance (REL) of this information hierarchy is that the reader is oriented towards a negative disposition on Tinubu's emergence as president. The journalist furthers this line of thought with the nominalization of the election as being *controversial*. The use of (REF) to categorize the candidates have metaphorical evocations (MPH) Peter Obi is portrayed as being the better candidate because he was popular among young people. Atiku Abubakar is portrayed as being part of the political establishment by referring to him as vice president and only Tinubu's age is mentioned as being a 70-year-old. The mentioning of his age is a pract to draw attention to his weakness starkly contrasted with the candidate popular among young people. The (REL) of foregrounding the information about the Labour party's reaction to the election result is another pract of bias. Choosing to present the quotation of the *lesser-known Labour party,* further presents the party in favourable light. With the journalistic convention of presenting the most important information first, the Labour party's views are thus presented as being the most important.

Excerpt 22 *CNN* news website (March 2023, https://edition.cnn.com/2023/02/28/africa/nigeria-presidential-election-result-intl-hnk/index.html)

Kingmaker turned king

After decades spent behind the scenes, Tinubu launched his campaign for the presidency with the motto: "It's my turn." He will become Nigeria's fifth elected president since 1999, winning the race for the country's top job on his first attempt. Vote counting since Saturday's polls has been vehemently challenged by many who allege the process has been marred by corruption and technical failures. On Tuesday, the country's main opposition parties described the results of the election as "heavily doctored and manipulated" in a joint news conference.

Pragmatic Analysis

In excerpt 22, the subheading is textually foregrounded. The reference (REF) of Tinubu as king and kingmaker implies that Tinubu's candidacy and impending presidency are monarchical in negation to Nigeria's democratic system of government. The allusion to a past role as a kingmaker and his transition to becoming a king relays the information that Tinubu has not followed the free and fair route to the presidency.

The pract ascribed to Tinubu "*It's my turn*" can be seen as a directive performative, where he is expressing his intention to run for president and uses the assertive performative to convey his sense of entitlement. Tinubu's use of the phrase *"It's my turn"* carries the pragmatic meaning of entitlement or expectation, suggesting that he believes it is his time to hold the presidency. Buhari's congratulatory statement can be seen as an expressive performative, where he is expressing his feelings of approval and support for Tinubu. This carries the pragmatic meaning of endorsement and approval, indicating his support for Tinubu as his successor. The Labour Party's statement describing the election results as "*heavily doctored and manipulated*" is an expressive performative, whereby they claim the election process was flawed. The opposition's statement carries the pragmatic meaning of protest and accusation, suggesting that they believe the election results were not fair or accurate.

5.0 Discussion of Findings

The foregoing pragmatic analysis established textual evidence of framing techniques used by the journalists in reporting the results of Nigeria's 2023 presidential elections. The following is a discussion of key findings guided by the article's delineated research questions.

In answering research question 1, what are the pragmatic framing techniques used in selected online news reports on Nigeria's 2023 presidential elections? The study found that the journalists in this study, made specific lexical selections and choice of utterances out of the vast array of choices in their lexicon to evoke frames which characterize elections as a competitive sport and warfare where winners emerge and losers are vanquished. Textual evidence arises from the use of metaphors which carry connotations quite different from literal meaning. Just as Arseneault (2016) defines metaphors as a figurative embellishment of language in which the utterance's literal meaning is different from the conveyed proposition, metaphors function to ascribe the features of one thing on another. Essentially two concepts juxtaposed and compared.

One example of the use of metaphors to characterise elections as a competitive sport, arises in Excerpt 12, the lexical selection of the adjectival "*frontrunner*" is a metaphorical pract (MPH) which evokes the mental construct and comparison of an election to a race wherein the frontrunner is the winner of the competition.

Hence the election is not thought of as a democratic process whereby the electorate chooses their leader, rather it is described as a party race in which the fastest runner with the skills to beat competitors wins. In this scenario, Tinubu is also characterized as the candidate facing opposition from even within his own party. In this case, the journalist also draws on contextual knowledge, inferring the assumed shared situational knowledge (SSK) of Tinubu's wealth. This is inferenced (INF) to further depict Tinubu as a warrior who won because he had the most financial resources in his "*war-chest*". The performative function of the utterance is an expressives. This is because sentence adverbials *frontrunner and foisted* relay the journalist's attitude towards the truth condition of the proposition according to Searle (1969).

Excerpt 2 from the Punch newspaper, also furthers the narrative of metaphorical use of language to represent elections as a competitive race. Here elections are characterised as a competitive race. The phrase "*The three leading candidates won while kwankwaso only claimed Kano state*" evokes the metaphorical frame (MPH) of identity politics and party loyalty. The journalist could have just written "*the three candidates*" and identified them by name. However, the pract of choosing to use the adjective "*leading*" to modify the noun candidates, frames the candidates as superior to Kwankwaso. The use of the adverb "*only*" is also a pract which modifies Kwankwaso's achievement limiting him as inferior in comparison to the other candidates. The lexical choice of the verbs "e*dged", "ousted",* and the noun *"challenger"* furthers the framing of elections as a fierce competitive race. The relevance (REL) of presenting the information that Tinubu won the elections at his first attempt, portrays Tinubu as a strategic and successful leader, and influential candidate. This evokes the metaphorical frame (MPH) of leadership being associated with Tinubu. This is furthered by the use of phrases such as "*leading the coalition*", and "*extended his influence*". The narrative structure of presenting a chronological progression of Tinubu's political career from senator to governor, and now president, presents a storyline of logical progression and growth. This positive framing of Tinubu as a strategic and influential leader, may lead readers to the inference (INF) that he is a credible leader and his victory may be perceived as well-earned.

Excerpt 3 which reads: (*Aside from Tinubu; Obi; Atiku, and Kwankwaso, other candidates that gunned for the nation's oval office...*) continues the warfare metaphor. Another example can be found in Excerpt 1. The journalist's lexical choice of the phrase "*INEC Declares Tinubu winner*" is a frame which connotes a competition where a winner emerges and others loose out. In this case "*winner*" is a metaphorical frame which evokes the mental construct of a competitive sport.

An alternative choice of words could have been *INEC declares Tinubu President*. However, making the lexical selection of the noun "*winner",* an expressive, over the choice of a seemingly neutral noun : *president*, is a pragmatic act (pract) which frames elections as a competition among candidates. Excerpt 12 also presents textual evidence of the use of metaphors (MPH) to characterize elections as competitive warfare. Excerpt 12 reads thus "*This message was read as meant for Tinubu, who was the frontrunner for his party's nomination. Against all odds, with the support of nine APC Governors from Northern Nigeria, the use of his war-chest, etc., Tinubu emerged as APC's presidential candidate.* The underlined serve to reference and characterise Tinubu as a winner. This begs the question; how should other candidates be characterised? If one person is singled out as winner, the logical assumption follows that the others have lost out. Evidenced by the foregoing examples, the use of metaphors by journalists in this study connotes a frame wherein Nigeria's 2023 presidential elections was presented as a competitive sport, race or warfare. The pragmatic description of metaphors highlights the fact that the metaphors used elicit and convey a different meaning from what is actually said. The journalists use of language evokes meaning and inferences, different from literal meaning. Metaphors are essentially nonstandard and deviate pragmatically from ordinary literal language. The use of metaphors here transfers the qualities of warfare, competitive sports and racing to the democratic conduct of elections, in which case this comparison does not necessarily meet the felicity conditions for the description.

In answering research question 2, how are pragmatic techniques used to frame reportage in the selected online news reports? Evidence can be found in the foregrounding of informational content. For example, the use of headlines pragmatically frames the informational content of the headline as more important than other parts of the news report. The inverted pyramid style of news writing also frames informational content in a hierarchical scale whereby the most important information is presented before the least in a descending order. Textual evidence can be found in Excerpt 6: *KING AT LAST!: Tinubu's Long Journey To President.* The excerpt is the headline of the news report. With journalistic writing being hinged on maximising informational content for the reader based on relevance, the journalists and editors have made this specific linguistic choice of headline as a title which is foregrounded to capture reader's attention. The headline uses "*King"* as a metaphor which evokes a sense of monarchy. The journalist's choice of headline potentially elicits inferences that Tinubu's emergence as president is more of a royal ascension than a popular vote election by the Nigerian people. It also conveys a sense of victory over the vanquished, thus positioning Tinubu as a dominant figure.

The prepositional phrase *at last* also infers that it has been a long-term plan for Tinubu to be president. The use of the exclamation mark signals the pragmatic act of assertion, a sweeping emphatic statement. In terms of performative function, this head line is an assertive. Assertives according to Searle's (1969) theory, are utterances which commit the speaker to the truth value of the proposition. In this case, the journalist in making this choice of lexical selection asserts that Tinubu is indeed a "*King*". For the fact that the headline is not attributed to anyone else, the inference is that this is the voice of the reporter or the opinion of the *Leadership* editorial board. According to The Missouri Group (2014), editors are the gatekeepers who decide the newspaper's standpoint on key issues. Due to the gravity of election results, it is expected that this particular headline will not be published without proper vetting. The use of the lexical item "*journey*" is also a metaphor (MPH) which elicits the inference (INF) that Tinubus' emergence has been a long and perhaps painstaking process. A "*long journey"* in which readers may be oriented to sympathize with Tinubu's personal struggle culminating in a hard-won success. The relevance (REL) of the possessive apostrophe "s" in "*Tinubu's Long Journey*" is a pragmatic act (pract) which points to Tinubu's personal ambitions being framed as more important than the political event. This personalization also frames the informational content in such a way that Tinubu is foregrounded as being the focal point of the news story.

In excerpt 4, the narrative structure of presenting a chronological progression of Tinubu's political career from senator to governor and now president, presents a storyline of logical progression and growth. This positive framing of Tinubu as a strategic and influential leader, may lead readers to the inference (INF) that he is a credible leader and his victory may be perceived as well-earned. In addition to conspicuously positioning information, the associations of words with familiar cultural symbols for the reader is another means through which frames are evoked. An example of this frame can be found in Excerpt 18. The excerpt associates the cultural symbol of traditional drummers to evoke a frame of celebration. This draws on the shared situational knowledge (SSK) and infers (INF) that the celebrations were limited to candidate Tinubu's strongholds alone. The (REL) of the information that "*Some partied into the early hours in Lagos, even though he was defeated by Mr Obi in the city. The normally bustling streets of Lagos are relatively quiet on Wednesday",* is to foreground the information that Tinubu lost his home state.

Again, the journalist's use of the adjectival, "*the normally bustling street of Lagos"* is another pract to portray the uncertainty that followed the announcement of Tinubu's victory in the presidential election. The above-mentioned examples are textual evidence of how the foregrounding of informational content, the use of headlines, the inverted pyramid style of news writing and association of cultural symbols are used as framing techniques to orient readers towards a particular worldview. This answers research question 2: how are pragmatic techniques used to frame reportage in the selected online news reports? Evidence was found in the use of headlines to pragmatically frame the informational content of the headline as more important than other parts of the news report and the inverted pyramid style of news writing which also frames informational content in a hierarchical scale whereby the most important information is presented before the least in a descending order.

In answering research question 3, what is the contextual relevance of framing techniques in the selected online news reports? The study found that certain frames call attention to ideas embedded in culture. Hence framing techniques were used to link cultural symbols and artefacts to certain point of views or worldviews, thereby orienting readers towards a particular stance on socio-political issues. This was achieved by linking metaphors to culturally relevant concepts and symbols. These associations highlight memorable artefacts of culture, ideology and history. The connotations then evoke ethnic sentiments already embedded in the Nigerian society. This potentially colours the perception of readers about particular issues. By acknowledging the ethnic affiliations and religious inclinations of candidates, the frames establish links between culture and political outlook. As such, cultural references can be used to influence readers to identify either positively or negatively with certain candidates. This can further in-group and out-group dynamics. One consequence of group segregation is the alignment with certain values, political perspectives and the reinforcement of stereotypes and biases. If the news report aligns with a particular group, it then frames that group positively over an out-group. For

example, the BBC news report characterised Tinubu using his ethnic identity as quoted. "*He <u>campaigned for the presidency under the slogan: "Emi lo kan", which means "It's my turn" in Yoruba.*"* The relevance (REL) of including the slogan *Emi lokan* further frames Tinubu as a self-centered politician who is focused on pursuing his own interests. The journalist also misrepresents the circumstances surrounding the emergence of the catch phrase *E mi lo kan*. The phrase was not an official campaign slogan. Rather, it emerged during a speech on the 3rd of June 2023 in Ogun state, while Mr. Tinubu was addressing members of his own party.

 In his speech to APC delegates ahead of the party's primaries, the Guardian newspaper quoted Tinubu as saying "It is my time, I am educated, I am experienced, I have been serving people for a long time. Bring me the presidency it is my turn". Hence the BBC journalist's out of context quote is a pract which misrepresents the circumstances surrounding the pract "*Emi lokan*". The use of framing techniques by journalists has weighty implications for peaceful coexistence. In a multi-ethnic, and multi-religious country like Nigeria, journalist can either promote peace or incense the public with their reportage.

5.1 Conclusion

This article demonstrated how some journalist's choice of words frame news and potentially orient readers towards certain points of views or worldviews. In highlighting the potentials to shape the public's understanding of information for peaceful co-existence or otherwise, the findings resonate with the theme of this conference: Uniting Research Efforts: Combating Security Issues in North-East of Nigeria. This is evidenced by the important role of the media and journalists in fostering peace. The process of news reporting is a constructed form in which journalists shape the context and mode of information presentation. Consequently, the news shapes the viewpoints of the audience and bears great impact in combating security problems. In national elections, the imperative for credible information dissemination is vital for peaceful existence. Especially in a multi-religious and ethnically diverse country like Nigeria. Elections are an important governance process in democratic societies.

In Nigeria, the huge population of over two hundred million according to the World Bank (2024), makes elections a complex process. In the North-east region, the threat of the Boko Haram insurgency, kidnappings and economic downturn highlight the urgency of the situation and need for continuous peacebuilding and development. This research's findings prove that the media's framing of the news can be a tool for combating insecurity and promoting peace and development. Nigeria's huge population and economic potential makes the country a significant factor in global discourse and power relations. In the digital world of online news, misinformation and disinformation loom large. They bear dangerous implications for peaceful coexistence for the citizenry. Selective reporting of information can have incendiary repercussions for society. By shaping the reader's understanding of the world, the interpretation of important events such as elections, can either spark crisis or temper emotions and inspire peaceful co-existence.

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CYBER SECURITY AWARENESS IN DEVELOPING COUNTRIES IN AFRICA: LESSONS FROM NIGERIA

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ABSTRACT

This research investigates the dynamics of cyber security awareness in the African context, drawing insightful lessons from Nigeria's experience. With the escalating digital landscape across Africa, understanding the role of cyber security awareness becomes crucial. This study delves into the multifaceted dimensions of cyber security awareness programs, exploring their design, implementation, and impact. It sheds light on Nigeria's unique position as a prominent player in the African technological landscape and examines how its initiatives have contributed to enhancing cyber security awareness. By dissecting Nigeria's strategies, challenges, and successes, this research abstract identifies key lessons that can be extrapolated to other African nations. Through a meticulous analysis of Nigeria's cyber security awareness initiatives, this research uncovers strategies that have effectively engaged various sectors of society, including government, private industry, and civil society. Furthermore, the research delves into the challenges encountered, such as the digital divide and evolving cyber threats, which provide insights into tailoring awareness campaigns to address region-specific concerns. The work also shed-light on how Nigeria's experiences highlight the importance of collaboration between national and international stakeholders in bolstering cyber security resilience. By extrapolating these lessons, this research underscores the potential for other African countries to adopt similar strategies, thus fortifying their cyber security landscapes.

KEYWORDS: Cybersecurity, Africa, Nigeria, Digital.

1   **INTRODUCTION**

INTERNET IN NIGERIA

The internet, an interconnected global network of information and communication, has become an indispensable part of modern life. Its journey from inception to ubiquity has been nothing short of innovation, as it has also transformed the way we perceive the world: "The electromagnetic discoveries have recreated the simultaneous 'field' in all human affairs, so that the human family now exists under conditions of a 'global village," stated Marshal McLuhan[1].

McLuhan's concept of the global village refers to the entire world coming together under the tent of technology, with diverse locations across the globe having the potential to connect. Studies reveal that the evolution of the internet is not a one-time engulfing phenomenon; many parts of the world joined the train as the digital tide surged. Nigeria, once dominated by traditional forms of communication, witnessed the pioneering introduction of the internet in the early 1990s.

Spearheaded by the Nigerian government, in 1991, the country's first Internet Service Provider (ISP), named The National Center for Communication Technologies (NCCT), and was founded. This dawn of the modern internet age paved the way for a digital revolution. More ISPs like Nitel, Interswitch, and Vee Network came into the picture in the mid-1990s, with increasing investments in technological infrastructure to establish reliable internet connectivity[2].

6th Despite the limited online representation of Nigerians in 1999, internet accessibility in Nigeria underwent swift expansion during the early 2000s. On August, 2001, the mobile system was introduced to the Nigerian market and society, marking the third year of former President Olusegun Obasanjo's initial term[3].

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[1] Georgiadou, "McLuhan's Global Village and the Internet."

[2] "Detailed History of Internet in Nigeria - History of Nigeria."

[3] Ubabudu, "The Effectiveness of Global System Mobile Providers' Services on Communication in Nigeria."

The introduction of GSM technology to the nation led to a sudden or gradual cessation of the troublesome and extensively criticized offerings of the Nigerian Telecommunications Limited (NITEL), which previously held a monopoly on telecommunications and data services in Nigeria. Right from the beginning, it was evident that the emerging era of wireless communications held superior services, prospects, and commitments for Nigerians.

ECONET Wireless is credited with placing the first live GSM call in the country on June 8, 2001[4], making it the inaugural network provider to do so. MTN quickly followed suit, being established on May 16, 2001, but its operations commenced in August of the same year. Initially, the Nigerian government granted licenses to only three companies: Econet Wireless, MTN, and MTEL. GSM services were initially introduced in Lagos, followed by Abuja, and then Port Harcourt. The new calling services were launched within the 900 and 1800 MHz spectrum, with charges set at N50 per minute due to the absence of a per-second billing system. This system persisted until Mike Adenuga's Globacom Nigeria Limited (Glo) entered the market in 2003, introducing per-second billing.

A report from the International Telecommunications Union focused on telecommunications development across nations from 1996 to 2009. Updated in July 16, 2010, the data regarding Nigeria revealed that internet usage among every 100 individuals surveyed in 1996 was at 0% and remained consistent for four years. Only by the close of the year 2000 did this figure rise, albeit insignificantly, to a surprising 0.3%. From 2002 to 2004, the percentage climbed to 1.5%. As stated by Adomi in 2005, Nigeria had a total of 750,000 internet users, representing 0.5 percent of the population by late 2003. Four years later, in 2007, this percentage escalated to 7%, and rapidly ascended further in 2008, reaching a peak of 15.9%[5].

Since then, there has been consistent exponential growth in the sector, with about 100-120 million Nigerians connected to the internet as of 2019 (NOIPolls, 2019; Russon, 2020). This growth in the number of internet users in 2019 was much expected after the 28 million internet users recorded in 2012 jumped impressively to 103 million users in May 2018. This figure suggests that only 55% of the Nigerian population is connected to the internet.

In 2020, the Nigerian government projected to increase broadband accessibility and have 70% of the population connected to broadband by 2025. This can be linked to the surge in internet subscriptions witnessed in the country, as the Nigerian Communications Commission recorded that the first quarter of 2023 saw the number of internet users grow by 1.7%, with over 2.7 million new internet users, making the total number 157.5 million as of March 2023, added to the 154.8 million recorded in December 2022[6].

However, challenges emerged alongside progress. Cyber security and privacy concerns underscored the need for robust online protection measures, as cybercrime is a growing trend with the internet's continued penetration into every sector of society and the expanding digital landscape. In November 2022, Business Day, a national newspaper, reported that Nigeria recorded a 174% increase in cybercrime in six months, solidifying its 16th position in the world cybercrime ranking.

Nigeria, like many other countries, faces specific challenges when it comes to cybercrime. Factors such as limited cyber security awareness, weak legislation and law enforcement, and socio-economic conditions contribute to the prevalence of cybercriminal activities. It is imperative for individuals in Nigeria to be vigilant and take proactive measures to protect themselves from cyber threats, particularly on social media platforms. Oni Damilola et al "Cybercrime On Social Media In Nigeria: Trends, Scams, Vulnerabilities and Prevention 2023[7]"

Given the intricate nature of cyber security, it's evident that a crucial approach to mitigating its impact involves the formulation of stronger regulations and the steadfast enforcement of these laws. With the ongoing expansion of the digital landscape and the increasing sophistication of cyber threats, fostering an innovative culture requires an unwavering commitment to sustained support and robust infrastructure. This research initiative is poised to thoroughly explore the multifaceted domain of cyber security, shedding light on the path towards a future for Nigeria that is digitally secure and empowered.

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[4] "Econet Founder Reveals Story behind Company's Downfall in Nigeria."

[5] "Study on International Internet Connectivity in Sub-Saharan Africa."

[6] Jaiyeola, "$461m Investment Gap Slows Nigeria's Internet Coverage."

[7] International School Vietnam National University - Hanoi, Vietnam et al., "Cybercrime On Social Media In Nigeria."

2 THE POLITICAL ECONOMY OF CYBERSECURITY IN NIGERIA

Cybersecurity in Nigeria is shaped by a complex interplay of various actors, each with their roles, interests, and influence. The political economy of cybersecurity encompasses the following key players:

1. **GOVERNMENT INSTITUTIONS:** The government, through various agencies, plays a central role in shaping the cybersecurity landscape. It is responsible for creating the legal and regulatory framework, enforcing laws, and fostering an environment conducive to cybersecurity innovation. Key institutions include:

- **National Information Technology Development Agency (NITDA):** They Oversees IT development and cybersecurity policies, including the Digital Literacy and Capacity Development (DLCD) program[8].

- **NIGERIAN COMMUNICATIONS COMMISSION (NCC):** Regulates the telecommunications sector, which is critical for cybersecurity, especially concerning data protection and privacy.

- **Economic and Financial Crimes Commission (EFCC):** They Focuses on investigating and prosecuting cybercrime.[9]

- **NIGERIA COMPUTER EMERGENCY RESPONSE TEAM (NGCERT):** Coordinates responses to cybersecurity threats and incidents.[10]

2. **CIVIL SOCIETY ORGANIZATIONS (CSOS):** They play an important role in raising public awareness about cybersecurity issues, advocating for stronger protections, and providing education and resources to vulnerable populations. They often fill gaps left by the government, especially in rural areas where access to technology and cybersecurity education is limited.

3. **ACADEMIA:** Academic institutions contribute to the cybersecurity ecosystem by conducting research, developing new technologies, and training the next generation of cybersecurity professionals. Universities and research institutes are also key players in advancing theoretical and practical knowledge in cybersecurity, although Nigerian academic institutions often face funding constraints, which limit their capacity to conduct cutting-edge research and develop new technologies. Additionally, there is a gap between academic research and its practical application in the cybersecurity industry.

3   ROLES OF CYBERSECURITY AWARENESS IN DEVELOPING NIGERIA

The integration of the internet has become increasingly intertwined with our daily lives, encompassing not only individuals but also small businesses, large corporations, and even countries. Its remarkable evolution over recent decades has had a profound impact. Undoubtedly, the internet has significantly and positively influenced communication, opened up new business avenues, and provided countries with opportunities and capabilities for electronic governance. Virtually every aspect of human endeavor now relies on the internet, permeating our existence. With a diverse array of smart devices, advanced technologies, wireless connectivity, and the Internet of Things (IoT), accessing the internet has remarkably simplified both life and work, achievable with just a click or tap, as data seamlessly traverses the expansive realm known as cyberspace.

Cyberspace is characterized as an electronic medium or a virtual computer realm that interconnects various networks. The connections between these networks collectively create a multifaceted global network of computers, facilitating online communication among cyber users. The integration of the internet into everyday activities is so pervasive that many users unknowingly navigate between the physical world and the cyberspace. As data exchanges, encompassing activities like socializing, education, entertainment, and business, traverse cyberspace, there is a latent risk of malicious activities occurring. These malevolent acts, collectively termed as cyber crimes, pose a potential threat to cyber users, leading to damages that are often substantial and challenging to reverse.

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[8] "Cyber Security – NITDA."

[9] "Economic and Financial Crimes Commission - EFCC - EFCC Reaffirms Commitment to Fight against Cyber Crimes."

[10] "ngCERT | Security Quality Management."

As a computer-oriented crime, cybercrime revolves around criminal activities involving a network, a computer, or networked devices. Generally, a computer, a computer network or a networked device is used to commit the crime or may even be the target of the criminal act [11]. Typically directed at compromising the security, privacy, and financial well-being of individuals, organizations, or countries, cyber crimes often result in reputational damage and financial losses. The targets of these criminal activities face significant threats that extend beyond digital breaches, impacting their overall integrity and economic stability. Ibrahim (2016), identified three primary factors contributing to cyber crimes in Nigeria: socioeconomic, psychosocial, and geopolitical. These factors, according to the author, present challenges to the statistical data used to analyze cybercrime incidents across the country[12].

The emergence of cybercrime has given rise to contemporary concepts, notably cybersecurity. Cybersecurity is essentially the practice of safeguarding computers, servers, mobile devices, electronic systems, networks, and data from malicious attacks. However, the effectiveness of cybersecurity relies heavily on the awareness and consciousness of cyber users. Consequently, awareness and education constitute the primary defense against cybercrimes. Oforji et al (2017), conducted a study on cybersecurity and its associated challenges in Nigeria, providing recommendations to address the growing threat of cybercrime. Similarly, in the work by Uwadia and Eti, (2018), the authors emphasized that the escalating unemployment rates contribute to the increasing incidents of cybercrime in Nigeria. Despite these challenges, the legislative branch has taken a step by passing a bill to address issues related to cybercrime.

In a separate study, Osho et al (2015) presented a qualitative analysis of the cybersecurity policy and strategy in Nigeria. The authors examined the Nigerian National Cyber Security Policy and Strategy by employing selected harmonized strategy developmental frameworks and conducted a comparative evaluation with similar documents from other chosen nations. The findings revealed that, while the document largely met expectations in terms of content, it overlooked certain critical aspects affecting cyber security across various sectors of the Nigerian economy. Dambo et al (2017), in their exploration of cyberspace technology, underscored that cyber security has evolved into a matter of national concern in Nigeria due to the significant threat posed by cybercrime activities. Despite the incorporation of built-in firewall security software in modern computers and mobile phones, the authors argued that these technologies are not entirely foolproof, leaving users' information vulnerable. Hassan et al (2012), identified urbanization, unemployment, and ineffective enforcement of cybercrime legislation as causative factors for cyber crimes in Nigeria. The authors recommended that individuals or corporate entities take proactive measures to safeguard their IT infrastructure, emphasizing the necessity for the government to rigorously enforce cybercrime laws.

According to Oni et al (2023), Nigeria, a country with a population of over 200 million had over 31.6 million active social media users. With most popular social media platforms with WhatsApp having over (95%) users, Facebook having over (88.8%), Facebook Messenger having over (69.9%), Instagram having over (69.4%) and Twitter having over (61.2%). With a high number of users this social media platform is the most popular social media platform used by cybercriminals in Nigeria. These platforms are popular because they allow cybercriminals to reach a large number of people and to build trust with their victims.[13]

Considering Nigeria's expanding population of cyber users (Nigerian Bureau of Statistics, 2020), there is an anticipation of increased information exchange within the cyberspace, making it susceptible to exploitation. Safeguarding this information has become crucial for cyber user security and economic stability. Hence, the role of cybersecurity awareness among users becomes pivotal in thwarting cyber-attacks by online predators and ensuring overall cybersecurity. It underscores the importance of proactive measures and education in fortifying the digital landscape.[14]

4.   **COMBATING CYBERCRIME AND MALICIOUS COMPUTER ACTIVITIES IN NIGERIA**

Cybercrime, which refers to illegal activities conducted using computers and the internet, including hacking, phishing, online fraud, identity theft, and more, exploits digital technology to steal, deceive, disrupt, or harm individuals, organizations, or society, posing significant risks to data security, privacy, and financial well-being. The term "cybercrime" can be used to describe any criminal activity involving computers or the internet network (Okeshola, 2013)[15].

According to Maitanmi (2013), cybercrime is a complex phenomenon. He describes it as more than just defrauding individuals; it involves criminals utilizing computers as tools and the internet as a means to achieve various objectives.

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[11] "What Is Cybercrime?"

[12] "Social and Contextual Taxonomy of Cybercrime: Socioeconomic Theory of Nigerian Cybercriminals - ScienceDirect."

[13] International School Vietnam National University - Hanoi, Vietnam et al., "Cybercrime On Social Media In Nigeria."

[14] "Cybersecurity and Cybercrime Combatting Culture for African Police Services | SpringerLink."

[15] Galle, "A Historical Assessment of Cybercrime in Nigeria: Implication for Schools and National Development."

These objectives can include illegal downloading of music files and films, piracy, spam mailing, and similar activities. Cybercrime often arises from the misuse or abuse of internet services[16].

As our world becomes increasingly interconnected, these developments allow for enormous gains in productivity, efficiency, and communication. However, they also create vulnerabilities that can potentially devastate a country. The threat of cybercrime has grown exponentially, posing substantial challenges to nations worldwide. This pervasive global issue has firmly established its presence within the borders of Nigeria.

The concept of cybercrime has a historical background. It was found that the first published report of cybercrime dates back to the 1960s, occurring on mainframe computers (Maitanmi, 2013)[17]. At that time, these computers were not connected to the internet or other systems, and the perpetrators were often employees within the company. Therefore, it was referred to as computer crime rather than cybercrime.

In Nigeria, cybercrime has emerged as a primary avenue for embezzling money and conducting business espionage. According to the Nigerian Deposit Insurance Company's report, Nigeria incurred losses of 15.15 billion Naira (approximately $43 million in 2019) due to fraud in the banking sector alone in 2018. This amount marked a staggering increase of 539% compared to the 2.37 billion Naira recorded in 2017, with cybercrime being the predominant contributor. The victims of cybercrime span across the financial sector, other institutions, and individuals in various jurisdictions. Internet fraud is primarily motivated by financial gain[18].

Internet fraud can be traced back to Advanced Fee Fraud, a fraudulent scheme believed to have originated in West Africa[19]. This scheme has gained global recognition, particularly being associated with Nigeria, which has led to its nickname "Yahoo-Yahoo," with the "419" code referring to Nigeria's criminal code for fraud. In addition to having one of the highest average losses per victim, Nigerians are also reported to engage in the second most reported cyber crimes. According to Symantec Corporation and the African Union, a significant portion of online scammers use Nigerian Internet Protocol (IP) addresses, with 46% of the email addresses associated with these scams originating from Nigeria.

According to Check Point, a global cybersecurity vendor, as of 2016, Nigeria was ranked as the 16th highest country in terms of vulnerabilities to cyberattacks in Africa (Ewepu, 2016). This prevalence of cybercrime not only compromises the nation's efforts to uphold national security but also fosters negative perceptions that leave a lasting mark on the country's global reputation. A significant factor contributing to the widespread growth of cybercrime in Nigeria is the prevalent issue of unemployment and poverty. The country faces an unemployment rate of 23.1%, with youth unemployment accounting for a substantial 55.4% of that figure. Nationally, a staggering 40.1% (approximately 82.9 million people) of Nigerians are living below the poverty line. Furthermore, four out of every ten individuals in Nigeria have per capita expenditures that fall below N137,430 (equivalent to $355) annually[20].

The number of Nigerians apprehended for fraudulent activities conducted through broadcasting stations is notably higher compared to citizens of other countries. To gauge the severity of cybercrime in Nigeria, it is essential to analyze past convictions of individuals engaged in such activities. For instance, in 2019, a notorious Nigerian cybercriminal, Ramon Olorunwa Abbas, widely known as "Hushpuppi," was arrested and subsequently convicted for his participation in a global cyber fraud scheme. His case attracted international attention, highlighting the scale and audacity of cybercriminal operations originating from Nigeria. Likewise, in 2020, a Nigerian man named Obinwanne Okeke, commonly known as "Invictus Obi," faced conviction in the United States for masterminding a multi-million-dollar online fraud scheme. These prominent cases not only illustrate the international reach of Nigerian cybercriminals but also underscore the urgency of implementing comprehensive cybersecurity measures within the country.

Nigeria has implemented various preventive measures to combat cybercrime. These measures include the establishment of organizations such as the Nigerian Communications Commission (NCC) and the Nigeria Computer Emergency Response Team (ngCERT) to oversee cybersecurity and respond to cyber threats. The Economic and Financial Crimes Commission (EFCC) primarily focuses on investigation, while the Nigerian Police Force maintains a dedicated cybercrime unit tasked with cracking down on internet fraud. Furthermore, the Cybercrime (Prohibition, Prevention, etc.) Act of 2015 provides a legal framework to address various forms of cybercrime.

In recent years, Nigeria has also emphasized cybersecurity awareness and education to help citizens protect themselves from online threats. While progress has been made, the fight against cybercrime remains an ongoing challenge, given the

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[16] Ahmad, "CYBER CRIME AND THE SOCIOLOGICAL IMPLICATION IN THE NIGERIA'S TERTIARY EDUCATION SYSTEM."

[17] Galle, "A Historical Assessment of Cybercrime in Nigeria: Implication for Schools and National Development."

[18] Tade, "Electronic Banking Fraud in Nigeria."

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[20] Tredger, "Mobile-First Status a Chink in Africa's Security Armour?"

evolving nature of digital threats. Continued efforts in legislation, technology infrastructure, and international collaboration are essential to curb cybercrime in Nigeria effectively.

5 LESSONS LEARNED IN CYBERSECURITY AWARENESS FOR NIGERIA

Nigeria's rapid digital transformation presents both exciting opportunities and significant challenges. As the nation embraces the power of the internet and mobile technology, ensuring the safety and security of its citizens online becomes paramount. Here, we delve into key lessons learned from Nigeria's journey in raising cybersecurity awareness, highlighting both successes and areas for improvement.

1. **EARLY AND CONTINUOUS EDUCATION: BUILDING A GENERATION OF CYBERSECURITY AWARE CITIZENS**

At the heart of a robust cybersecurity posture lies a well-informed citizenry. Nigeria has recognized this crucial element, and efforts to integrate cybersecurity education into the national curriculum at all levels are a positive step towards building a generation of cybersecurity aware citizens.

Laying the Foundation:

- **Starting Young:** Integrating cyber security lessons into the primary school curriculum equips young Nigerians with a fundamental understanding of online safety from a young age. These lessons can focus on basic concepts like strong password creation, identifying suspicious emails, and responsible online behavior.
- **Age-Appropriate Progression:** As students' progress through secondary and higher education, the complexity of cyber security education should increase. This could involve topics like cyber bullying, social engineering tactics, data privacy principles, and secure browsing habits.
- **Interactive Learning:** Traditional classroom lectures can be complemented with interactive learning methods. Gamified simulations, ethical hacking scenarios, and online quizzes can make learning engaging and ensure students retain key concepts.

Initiatives and Role Models:

- **The National Information Technology Development Agency's (NITDA) "Digital Literacy and Capacity Development" (DLCD)** serves as a model for equipping young Nigerians with the foundation for safe online practices. The DLCD provides resources and training programs for educators, ensuring they can effectively deliver cyber security awareness lessons.

Beyond the Classroom:

- **Parental Involvement:** Educating parents and guardians is crucial. Workshops on online safety for parents can equip them to guide their children's online activities and reinforce cyber security best practices learned at school.
- **Community Outreach Programs:** civil society organization and non-profit organizations can play a vital role in raising cyber security awareness through community outreach programs. These programs can target specific demographics, such as rural communities with limited access to technology, and provide training in local languages.

The Benefits of Early Education:

By integrating cyber security education into the national curriculum at all levels, Nigeria can reap several benefits:

- **Empowered Citizens:** A populace equipped with cyber security knowledge can make informed decisions online, reducing their vulnerability to cyberattacks.
- **Reduced Cybercrime:** A decrease in cybercrime incidents translates to less financial loss and a safer digital environment for all Nigerians.
- **Future-Proofing the Workforce:** By fostering a culture of cyber security awareness from a young age, Nigeria can create a future workforce equipped to handle the ever-evolving cyber threat landscape.

Challenges and Considerations:

- **Teacher Training:** Ensuring educators have the necessary skills and knowledge to deliver effective cyber security lessons is crucial.
- **Resource Constraints:** Limited resources can hinder the implementation of comprehensive cyber security education programs. Public-private partnerships and international collaborations can address this challenge.

- **Digital Divide:** Not all schools have equal access to technology. Bridging the digital divide is essential for inclusive cyber security education.

2.   BUILDING A CYBERSECURITY SHIELD: COLLABORATION IMPORTANT PARAMETER

Nigeria faces a complex cyber security landscape. No single entity can effectively address these challenges. Collaboration between government agencies, educational institutions, private companies, and civil society organizations (CSOs) is key to building a comprehensive cyber security strategy.

Fostering Synergy:

- **National Cyber security Council:** Establish a central National Cyber security Council composed of representatives from all stakeholder groups. This council can set national priorities, coordinate efforts, and ensure all voices are heard.
- **Information Sharing Platform:** Create a secure information sharing platform where stakeholders can share threat intelligence, best practices, and incident response protocols. This fosters faster detection and coordinated responses to cyber threats.

Government and Education Partnership:

- **Cybersecurity Curriculum Integration:** Collaborate with educational institutions to integrate cyber security education into the national curriculum at all levels. Equip students with the knowledge and skills to navigate the digital world safely.
- **Cybersecurity Scholarships and Training:** Offer government-sponsored scholarships and training programs for cyber security professionals. This can address the current skills shortage and build a robust cyber security workforce.

Public-Private Partnerships:

- **Joint Awareness Campaigns:** Develop joint public awareness campaigns with private companies to educate citizens of all ages about cyber security best practices. This can leverage the reach of private companies' communication channels to amplify the message.
- **Research and Development Collaborations:** Encourage collaboration between government agencies, universities, and private companies on cyber security research and development. This can lead to the creation of innovative solutions tailored to address local cyber security challenges.

The Role of Civil Society:

- **Grassroots Mobilization:** Civil society organizations can play a crucial role in mobilizing communities and raising awareness about cyber security in rural areas. This can bridge the digital divide and ensure everyone benefits from a secure digital environment.
- **Advocacy and Oversight:** Civil society organizations can advocate for stronger cyber security regulations and hold government and private companies accountable for data protection. This promotes transparency and builds trust in the digital ecosystem.

Challenges and Opportunities:

 Building Trust: Building trust between different stakeholder groups can be challenging. Fostering open communication and mutual respect is crucial for successful collaboration.

- **Resource Constraints:** Some stakeholders may have limited resources to participate in collaborative initiatives. Explore funding opportunities from international partners and encourage knowledge sharing to bridge this gap.

Benefits of Collaboration:

- **Unified Approach:** Collaboration fosters a unified approach to cyber security, ensuring all stakeholders are working towards a common goal – a safer digital environment for all Nigerians.
- **Leveraging Expertise:** Collaboration allows each stakeholder to contribute their unique strengths and expertise, leading to a more comprehensive and effective cyber security strategy.
- **Sustainability:** A collaborative strategy has a higher chance of long-term sustainability. By working together, stakeholders can ensure the continuous improvement of Nigeria's cyber security posture.

By fostering collaboration between all sectors, Nigeria can build a robust cyber security shield, protecting its citizens, businesses, and critical infrastructure from evolving cyber threats.

3. Fostering a Culture of Security in Nigerian Organizations

Nigeria faces a unique challenge in cyber security awareness. While technical solutions are crucial, building a culture of security within organizations is equally important. This means creating an environment where Nigerian employees feel empowered to make security-conscious decisions, report suspicious activity, and learn from mistakes.

Leveraging Nigeria's Strengths:

- **Community Focus:** Nigeria has a strong sense of community. Use this to build a collaborative security culture where employees feel a shared responsibility for protecting the organization.
- **Open Communication:** Nigerians are known for their direct communication style. Encourage open communication about security concerns and incidents, fostering trust and transparency.

Strategies for Nigerian Organizations:

- **Security Champions as Mentors:** Appoint respected and tech-savvy employees as Security Champions. These champions can provide culturally relevant guidance and answer questions in a familiar way.
- **Leverage Informal Communication Channels:** Many Nigerians rely on informal communication channels like WhatsApp groups. Consider using these platforms for security reminders and quick polls to gauge employee understanding.
- **Gamification with a Nigerian Twist:** Develop gamified security awareness programs that incorporate local references, humor, or even traditional proverbs to make learning engaging and memorable.

Addressing Challenges:

- **Fear of Retribution:** Some Nigerian employees may fear being blamed for security incidents. Address this by emphasizing a focus on learning and improvement, not punishment.
- **Limited Resources:** Many Nigerian organizations have limited resources. Look for cost-effective solutions, such as online training modules or peer-to-peer learning initiatives.

By implementing these strategies, Nigerian organizations can foster a culture of security that is both effective and culturally relevant. This will empower employees to become active participants in cyber security, ultimately leading to a more secure digital environment for businesses and individuals across Nigeria.

4. STRENGTHENING CYBERSECURITY REGULATIONS IN NIGERIA

Nigeria has made strides in addressing cyber security challenges, but gaps remain. Here's how strengthening regulations can create a safer digital environment:

A National Cyber security Framework:

- **Develop a comprehensive framework:** Nigeria needs a robust national cyber security framework that outlines clear standards and best practices for all stakeholders, including government agencies, businesses of all sizes, and critical infrastructure providers.
- **Sector-Specific Regulations:** In addition to the national framework, consider developing sector-specific regulations for critical industries like finance, telecommunications, and healthcare. These regulations should address the unique risks faced by each sector.

Focus on Data Protection:

- **Data Protection Law Enforcement:** Nigeria's Data Protection Regulation (NDPR) is a positive step. However, enforcement mechanisms need to be strengthened to ensure businesses comply with data security requirements. This can involve establishing a dedicated data protection authority and imposing fines for non-compliance.
- **Consumer Awareness:** Public awareness campaigns are crucial to educate Nigerians about their data privacy rights and how to protect their personal information online.

3. Collaboration between Regulators:

- **Cyber security Coordination:** Establish a central coordinating body to oversee cyber security efforts across different government agencies. This body can facilitate collaboration, information sharing, and a unified approach to cyber threats.
- **Public-Private Partnerships:** Foster public-private partnerships between government regulators and the private sector. This collaboration allows for knowledge sharing, joint capacity building initiatives, and the development of effective cyber security solutions.

Challenges and Opportunities:

- **Limited Resources:** The present government might face resource constraints in implementing and enforcing robust cyber security regulations, therefore it is advisable to explore international partnerships and capacity-building programs to address this gap.
- **Adapting to Evolving Threats:** Cyber threats are constantly evolving. Regulations need to be flexible and adaptable to address new and emerging risks.

Benefits of Strong Regulations:

- **Improved Security Posture:** Robust regulations set clear expectations and hold organizations accountable for cyber security. This strengthens the overall security posture of the Nigerian digital ecosystem.
- **Increased Investor Confidence:** Stronger cyber security regulations can demonstrate Nigeria's commitment to protecting sensitive data and critical infrastructure, potentially attracting foreign investment.
- **Empowering Consumers:** Data protection regulations empower Nigerian citizens by giving them control over their personal information.

By strengthening cyber security regulations and fostering collaboration between stakeholders, Nigeria can create a safer digital environment for businesses, individuals, and the nation as a whole.

5. **Building a Culture of Security: Empowering Employees through Security Champions**

A strong cyber security posture goes beyond technical solutions. Creating a culture of security within organizations is crucial, and Security Champions play a vital role in fostering this culture.

The Power of Peers:

- **Accessibility and Trust:** Employees often feel more comfortable approaching colleagues with questions or concerns than IT security teams. Security Champions act as trusted peers who can provide readily available guidance and support.
- **Promoting Best Practices:** Security Champions can lead by example, demonstrating best practices like strong password hygiene and secure browsing habits. This peer-to-peer influence can have a significant positive impact on overall organizational security posture.
- **Building Awareness:** Security Champions can organize awareness campaigns, distribute security tips, and conduct internal training sessions within their teams. This continuous reinforcement of cyber security practices keeps security top-of-mind for all employees.

The Role of Security Champions:

- **Answering Questions:** Security Champions can act as a first point of contact for colleagues with cyber security-related questions. This reduces the burden on IT security teams and allows for more immediate resolution of basic concerns.
- **Identifying Vulnerabilities:** By being embedded within teams, Security Champions can observe and identify potential security vulnerabilities in daily workflows. They can then report these vulnerabilities to the IT security team for mitigation.
- **Building a Sense of Shared Responsibility:** Security Champions play a crucial role in fostering a sense of shared responsibility for cyber security within organizations. By actively promoting secure practices and encouraging open communication, they create an environment where everyone feels accountable for protecting the organization's digital assets.

Developing Your Champion Team:

- **Selection Criteria:** Identify employees who demonstrate strong cyber security awareness, possess good communication skills, and are respected by their peers.
- **Training and Development:** Provide Security Champions with comprehensive training on relevant cyber security topics, communication skills, and best practices for championing a culture of security within their teams. Organizations

like the **Cyber Security Experts Association of Nigeria (CSEAN)** can play a valuable role in training and empowering potential Security Champions by offering specialized workshops and certification programs.

Benefits of a Security Champion Program:

- **Increased Employee Engagement:** Employees feel empowered and valued when they actively contribute to organizational security. This fosters a more engaged and security-conscious workforce.
- **Improved Incident Detection and Response:** Security Champions can help identify suspicious activity and encourage colleagues to report potential security incidents promptly. This allows for faster detection and response to cyber threats.
- **Enhanced Overall Security Posture:** By creating a culture of open communication and shared responsibility for cyber security, organizations can significantly improve their overall security posture.

Building a successful Security Champion program requires ongoing support and investment. By empowering employees through Security Champions, organizations in Nigeria can create a more secure digital environment for everyone.

6. **Prioritizing Mobile Security in Africa: The Nigerian Case**

Developing countries in Africa are witnessing a mobile revolution, with smartphone adoption on the increased. However, this increased reliance on mobile devices presents unique cyber security challenges. Here's how Nigeria can address these challenges by dedicating resources to mobile security:

Understanding the Threats:

- **Phishing on Mobile:** Nigerians are susceptible to phishing scams delivered via SMS or messaging apps. A very strong awareness campaign highlighting red flags of mobile phishing attempts should be carried out in all the nooks and crannies of the country.
- **Unsecured Public Wi-Fi:** Public Wi-Fi networks are popular in Nigeria, but often lack proper security. Users should be educated on the risks of using public Wi-Fi and promote the use of VPNs for added protection.
- **Malicious Apps:** Third-party app stores can harbor malware-infected applications. Encourage downloading apps only from official stores and educate users on reviewing app permissions before installation.
- **SIM Swapping Scams:** SIM swapping, where fraudsters take over a victim's phone number, is a growing threat in Nigeria. Advocate for stronger SIM registration processes and two-factor authentication for mobile financial transactions.

Resource Allocation Strategies:

- **Mobile-Specific Training Programs:** Design training programs specifically focused on mobile security best practices. These programs can be delivered through mobile learning apps, SMS alerts, or community workshops.
- **Public-Private Partnerships:** Partner with mobile network operators to develop and implement mobile security solutions. Mobile network operators can offer SMS-based security tips, promote secure mobile banking practices, and collaborate on public awareness campaigns.
- **Capacity Building for Law Enforcement:** Train all law enforcement agencies to investigate mobile cybercrime effectively. This includes training on forensics for mobile devices and international cooperation to track down cybercriminals operating across borders.
- **Incentivize Secure Mobile Development:** Offer grants or tax breaks to encourage developers to create secure mobile applications. This can promote the adoption of secure coding practices and secure payment gateways.

Leveraging Nigeria's Strengths:

- **Mobile Penetration:** Nigeria's high mobile penetration rate allows for widespread dissemination of security awareness messages through SMS campaigns or mobile apps.
- **Tech-Savvy Youth:** Nigeria's young population is tech-savvy and can be mobilized as advocates for mobile security. Partner with youth organizations to develop innovative mobile security awareness campaigns.

Challenges and Opportunities:

- **Digital Literacy Gap:** Not all Nigerians possess the necessary digital literacy skills to stay safe online. Address this by creating training programs in local languages and focusing on user-friendly security solutions.
- **Limited Resources:** Resource constraints may hinder the implementation of comprehensive mobile security initiatives. Explore public-private partnerships and international aid to bridge the funding gap.

By dedicating resources to mobile security and leveraging its unique strengths, Nigeria can create a safer mobile environment for its citizens. This will not only protect individuals but also foster a thriving mobile economy where trust and security are paramount.

7. Staying Ahead of the Curve: Continuous Improvement in Cybersecurity Awareness

The digital threat landscape is constantly evolving. Cybercriminals develop new tactics, and technology advancements introduce new vulnerabilities every day. Nigeria's cyber security awareness programs must adapt to remain effective. Here's how to ensure continuous improvement:

Staying Informed:

- **Threat Intelligence Gathering:** Establish mechanisms for gathering and analyzing threat intelligence. This could involve collaborating with international cyber security organizations or subscribing to threat feeds.
- **Regular Vulnerability Assessments:** Conduct regular vulnerability assessments for critical infrastructure and government systems. This proactive approach helps identify and address weaknesses before they can be exploited.

Program Evaluation and Updates:

- **Track Training Effectiveness:** Evaluate the effectiveness of cyber security awareness training programs through surveys, knowledge assessments, and phishing simulations. This helps identify areas where improvement is needed.
- **Update Content Regularly:** Refresh training content to reflect the latest threats and best practices. Include real-world examples relevant to the Nigerian context to keep learners engaged.
- **Adapt Delivery Methods:** Explore new and innovative ways to deliver cyber security awareness training. This could involve using gamified learning platforms, interactive simulations, or micro-learning modules delivered through mobile apps.

Building a Culture of Learning:

- **Promote Continuous Learning:** Encourage a culture of continuous learning within organizations. This could involve establishing cyber security newsletters, lunch-and-learn sessions, or internal knowledge-sharing platforms.
- **Employee Feedback Mechanisms:** Create feedback mechanisms for employees to provide input on cyber security awareness programs. This allows you to tailor programs to address employees' specific needs and concerns.

Leveraging Technology:

- **Automated Phishing Simulations:** Utilize automated phishing simulations to test employees' ability to identify and avoid phishing attempts. This helps employees stay sharp and adapt to evolving phishing tactics.
- **Security Awareness Platforms:** Consider implementing security awareness platforms that provide employees with on-demand access to training materials, security updates, and best practices.

Benefits of Continuous Improvement:

- **Enhanced Protection:** By staying informed and updating programs, Nigeria can ensure its citizens and organizations are equipped to address the latest cyber threats.
- **Increased Engagement:** Fresh and relevant content keeps employees engaged with cyber security awareness, leading to more effective behavior changes.
- **Adaptability:** A culture of continuous improvement allows Nigeria's cyber security awareness programs to adapt to the ever-changing digital landscape.

By prioritizing continuous improvement, Nigeria can create a culture of cyber security awareness that empowers its citizens and organizations to stay ahead of the curve and navigate the digital world with confidence.

6   CONCLUSION

Nigeria's journey towards a robust cyber security ecosystem necessitates a multifaceted approach. This research paper has explored key strategies for raising cyber security awareness, fostering a culture of security within organizations, and building a collaborative national effort. By acknowledging valuable lessons learned and addressing existing challenges, Nigeria can create a safer digital environment for its citizens and businesses.

Key Takeaways:

- **Early and continuous cyber security education** is fundamental, equipping young Nigerians with the foundation for safe online practices.
- **Targeted awareness campaigns** addressing the knowledge gap and utilizing diverse communication channels are essential.
- **Collaboration between government, educational institutions, private companies, and CSOs** is crucial for a unified national approach.
- **Building a culture of security within organizations** through Security Champions and open communication empowers employees and strengthens overall security posture.
- **Continuous improvement and adaptation** to evolving threats and technologies are necessary for sustained effectiveness.

Moving Forward:

- **Increase Investment:** Nigeria needs to prioritize investment in cyber security initiatives. Public-private partnerships and international aid can bridge the resource gap.
- **Capacity Building:** Continuous training and capacity building programs for IT professionals, educators, and Security Champions are essential.
- **Leverage Technology:** Utilizing innovative technologies like gamified learning platforms and mobile applications can enhance awareness programs and reach wider audiences.
- **Data-Driven Approach:** Collecting and analyzing data on cyber threats can help tailor awareness campaigns and resource allocation for maximum impact.
- **International Collaboration:** Nigeria can benefit from knowledge sharing and collaboration with international organizations and developed nations with established cyber security frameworks.

Building a secure digital future for Nigeria requires a collective effort. By implementing the strategies outlined in this research paper, fostering collaboration across sectors, and prioritizing continuous learning, the citizens can be empower, safeguard its critical infrastructure, and thrive in the ever-evolving digital landscape.

Looking Ahead:

This work provides a foundation for understanding the importance of cyber security awareness in Nigeria. Further work can be carried out on areas like:

- Developing a national cyber security strategy framework.
- The economic impact of cybercrime in developing countries in Africa.
- The role of artificial intelligence and machine learning in enhancing cyber security defense in Africa.

By building upon these efforts, Nigeria can navigate the complex digital landscape with greater confidence and create a future where digital opportunities flourish alongside robust cyber security.

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An Assessment of the Effect of Banditry on Food Security in Zamfara State, Nigeria

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Abstract
Banditry as a criminal act has significantly posed a challenge in Nigeria, specifically in Zamfara State, constituting threat not only to the safety and security of the residents but also to agricultural production, distribution, and access. The aim of the study is to assess the impact of banditry on food security in Zamfara State, analyzing its effects on agricultural production, food accessibility and food production. The study employed primary data which were collected through the use of the structured questionnaire. The result showed that factors such as destruction of farm lands, kidnapping, abduction of farmers, displacement of farmers, destruction of crops, and livestock, leads to reduced food production and availability. The research hypothesis was tested with Chi-square statistic ($\chi2$). The data analysis and hypothesis testing revealed that the Bandits' activities have significant effects on food production in Zamfara state ($\chi2$=62.58[a], α=0.05, df=10, p-value=0.001). The study highlights the need for integrated strategies to address the impact of banditry on food security, initiatives such as enhanced security measures, and support for farmers are recommended to mitigate the adverse effect of banditry on food security in Zamfara State.
Keywords: Farmers, Bandits, Food Security, Insecurity, Crime

1 Introduction
Banditry in Nigeria has emerged as a significant challenge, affecting various facets of societal life, particularly the agricultural sector and broader economic activities. Agriculture as the main stay of the economy in the North and major source of income for people in the region has been adversely affected by banditry. The activities of bandits are prevalent particularly in Kaduna, Zamfara, Katsina and other states in the Northwest region of Nigeria, although incidents have also been reported in the Northeast. The activities of these violent groups has given rise to displacements of persons, loss of lives and the erosion of the means of livelihoods for people in this region who depend primarily on farming. It is pertinent to note that of all the sectors of the Nigerian economy, the one most affected by banditry is the Agriculture sector. Activities of bandits has greatly hindered farming in the northwest. Farmers are killed, hindered from harvesting their crops and sometimes made to pay a fee to have access to their farmlands. A 2024 report by SB Morgan Intelligence claims that farmers pay between N70, 000 to N100, 000 to bandits to gain access to their farmlands. The report stated,

> *States like Kaduna, Katsina, Zamfara and parts of Jigawa remain particularly affected. For farmers in these areas, working on their farms poses a dual risk: either they attempt to harvest their crops with hopes of earning a living, or they pay hefty ransoms to save themselves from abductors. The decade-long crisis spells woes on agrarian communities, with locals witnessing more terror attacks than ever. This has spiked the cost of living in the region as food prices in the Northwest experienced a panic surge, worsening the challenge of food affordability in the region. Farmers say they have completely abandoned some parts of their farms because of these bandits. In recent years, a concerning trend has emerged in some communities affected by banditry in Nigeria. Farmers are now forced to pay levies to bandits to access their farmlands and harvest their crops. This practice, which began around 2019, has become more pronounced in subsequent years, particularly during the last farming season. As a result, millions of naira have been channeled to bandit groups through this shift towards farming taxation.*

Banditry according to the International Committee of the Red Cross is the gravest security threat that Nigeria currently faces, and it is driving her worst humanitarian crisis in decades. Banditry refers to the activities of criminal groups, who engage in various illicit activities including cattle rustling, kidnapping, and displacement of farmers in rural communities where agriculture is prevalent. The activities of these bandits have been on the rise in Zamfara State leading to serious insecurity especially regarding to food production thereby impacting food security.

Food security on the hand encompasses availability` of food, access to farm and food distribution and these are affected by the activities of these bandits. For instance, attacks of farmers which most times result in their displacement, destruction of crops, loss of livestock and invaluable, reduced food production.

2 Theoretical Frameworks Bordering on Banditry as a Social Problem

Two theories have been adopted to attempt an explanation of banditry as a social problem. These theories are: Social Disorganization Theory and Situational Action Theory.

1. Social Disorganization Theory

The social disorganization theory is a sociological perspective that focuses on the breakdown of social structures, such as family, community, and institutions, as the primary cause of deviant behavior and crime in certain neighborhoods or communities. When these social structures weaken or fail to function effectively, individuals are more likely to engage in criminal activities. This theory emerged from the work of sociologists like Clifford Shaw and Henry McKay in the early 20th century, who studied crime patterns in Chicago neighborhoods. They found that areas with high levels of social disorganization, such as poverty, unemployment, residential mobility, and ethnic heterogeneity, tended to have higher rates of crime and delinquency.

When applied to the issue of banditry, the widespread poverty, unemployment, and economic inequality in rural communities in Nigeria create conditions ripe for criminal activities such as banditry. Brenner (2021) emphasizes this point:

Banditry has become an appealing method of income in northwest Nigeria where weak governance, youth unemployment, poverty, and inequality have left people with depleted options for livelihood.

Limited access to education, healthcare, and economic opportunities can perpetuate cycles of poverty and marginalization, driving individuals towards illicit means of survival.

2 Situational Action Theory and Banditry in Nigeria

SAT is a theory of crime developed in 2004 by Per-Olof Wikström. It explains what moves people to action such as crime by incorporating ecological, criminological, sociological, and behavioral sciences. Crime is an action that violates the law and is a result of the interplay between an individual's exposure to criminogenic settings and the propensity for criminality. That is, an individual's time in an unsupervised or poorly governed space and level of self-control determine the occurrence of crime. SAT posits that crime is motivated by an individual's morality and the prevailing situation. People are responsible for their actions, but the causes of their actions are situational. Therefore, an act of crime is the product of a choice made after considering various alternative scenarios and stimuli presented by a particular situation. Thus, crime is committed when perceived as a worthwhile and suitable alternative, given the prevailing situation, and/or when a person fails to apply moral restraint.

The situational stance advanced by SAT rests on four major elements: the person (psychological make-up, experience, and so on), the setting (the environment an individual is exposed to), and the situation (choices resulting from interaction with the setting), and action (the person's behaviour). SAT explicates the notion that factors that induce crime are the same for all people, regardless of their age and criminal career stage. The theory argues that people's propensity to commit a crime is different, just as environments also vary. An individual's setting determines whether a crime will be committed or not. For example, an individual who struggles as a result of multidimensional poverty and finds themself in an environment without guardianship, but with certain escape options and resources, is likely to commit crime. Crime occurrence, therefore, is the interaction between an individual's crime propensity and the setting's criminogenic incentive.

SAT proposes the following key basic assumptions:

1. People are essentially rule-guided creatures. They express their desires and respond to friction within the context of rule-guided choices;

2. Social order is based on shared rules of conduct. Patterns in human behaviour are based on rule-guided routines;

3. People are the source of their actions. People perceive, choose, and execute their actions;

4. The causes of action are situational. An individual's particular perception of action alternatives, the process of choice, and execution of the action are triggered and guided by the relevant input from the person-environment interaction;

5. Crimes are moral actions. Crimes are actions that break rules of conduct (stated in law) in a particular circumstance.

SAT explains different crimes ranging from theft to terrorism. In explaining radicalization and terror, SAT highlights the key problems of vulnerability, exposure, and emergence. To develop crime propensity, the individual has to be exposed to crime-supportive moral contexts; a setting that induces crime must be present and the person in regular contact with it; and the individual has to be sensitive to the influence of the crime-supportive setting that they come into contact with.

When applied to banditry in Nigeria, SAT expounds on the interaction between the person, setting, situation, and action. The individual (especially with a low crime propensity) is motivated by the situation to consider crime as an alternative to realize the desired outcome. Because the individual is a product of the society they live in, they are likely to subscribe to society's norms. Following Wikström's postulations, crime results from an interaction between a person and the environment. Therefore, in a society characterized by criminogenic inducement, the individual becomes vulnerable to crime. The situation and settings thus motivate an individual's action. The psychological experience resulting from multidimensional poverty, exclusion, unemployment, marginalization, inequality, and displacement coupled with the prevailing circumstance in the setting, such as under-governed spaces, illegal mining activities, the influx of small arms and light weapons and a poorly equipped security apparatus, engenders a negative situation which encourages deleterious action (banditry). Put differently, the increase in banditry in Nigeria is attributable to the interactions among people who are victims of adverse socioeconomic conditions in the setting. The setting is characterized by recurring social malaise. Negative choices result from interaction with the setting, which leads to criminal action.

3 Evolution of Banditry in Zamfara State

The evolution of banditry in the northwest of Nigeria where it is prevalent has been attributed to environmental and ecological challenges in the region, which gave rise to fierce competition over scarce resources between nomadic Fulani herders and Hausa farmers. Brenner (2021) indicates:

In 2011 northwest Nigeria experienced a surge in bandit attacks between the nomadic Fulani herders and sedentary Hausa farming communities. Environmental and ecological changes caused land and water to become valuable commodities, sparking fierce, and often violent, competition over resources. Over the past decade banditry has evolved from a communal rivalry into lethal militia groups.

Several years down the line, herder-farmer clashes have not declined but instead has further exacerbated banditry to new heights as indicated by the 2022 Nigeria's Security Situation Analysis Report prepared by Nextier:

One of the factors responsible for the rise of banditry is the deteriorating farmer and herder relations. The sparse accessibility of grazing routes, pasture and water has become a deadly source of conflict.

In Zamfara State, where banditry has been rife, the origin of the menace has been attributed to the violent conflict that ensued between the Fulani and the Hausas in the state. This was stated in 2021, by the then Zamfara state commissioner for Information, Hon. Ibrahim Magaji Dosara, According to him,

The genesis of the conflict in Zamfara began with the killing of the most popular and highly respected Fulani leader in all the neighbouring states of Zamfara, Sokoto, and Kebbi, one Alhaji Ishe, of Chilin village in Kuyambana district of Dansadau Emirate in Maru Local Government Area of the state on the 11th of April 2013.

"Since then, Fulani in the 3 states became aggrieved and aggressive against Hausa communities from where the Yansakai who did the killing came from."

"The crisis began to worsen by the day through waves of attacks against each other and a series of revenge continued unabated. With the hostilities between the Fulani and Yansakai, each decided to form a formidable group and structure, the Fulani as bandits and Hausa as Yansakai, leading to the drawing of a battle line between them with increasing waves of attacks and counter-attacks, killing scores of innocent people, destruction of valuables and burning down of houses and foodstuffs. "

The above comments by Hon. Dosara highlights how underlying ethnic tensions, the absence of effective conflict resolution mechanisms, and the proliferation of armed groups contributed to the origin and perpetuation of banditry in Zamfara State.

4 Causes and Driving Factors of Banditry in Zamfara State

Banditry in Zamfara State is a complex issue with several contributing factors. Here are some of the key causes and drivers:

1. **Resource competition**: Competition over dwindling land and water resources between Fulani herders and Hausa farmers is a major source of tension. Climate change and decreasing rainfall have exacerbated this competition, leading to violent clashes. Water, which is an essential resource and vitally required for agriculture production, has been very scarce due to climate change and therefore is responsible for the farmers and herders conflict (Bello and Abdullah, 2021).

2. **Under-governance of Rural Areas:** Bandits exert their influence and terror on primarily underserved and ungoverned poor communities, further impoverishing the populace (Nextier, 2023). Limited state presence in rural areas hinders law enforcement and dispute resolution. Under-governed spaces coupled with the country's

porous borders have increased the influx of small arms and light weapons from the Sahel region – thus increasing the opportunities for crime (Akinyetun, 2022).

3. **Socioeconomic factors**: Akinyetun, (2022), argues that socioeconomic conditions prevalent in the North West, leaves the youth vulnerable to recruitment for criminal activities. High poverty rates and lack of economic opportunities, particularly among young people, make them more susceptible to recruitment by bandits.

Closely related to the above is unemployment among the youth, thereby making them susceptible to crime and criminality.

4. **Proliferation of firearms and criminal networks:** The easy availability of weapons fuels the violence and empowers bandit groups. The former Zamfara state commissioner for Information, Hon. Ibrahim Magaji Dosara, noted that the proliferation of both light and heavy weapons, with a high influx of bandits from neighboring countries worsened Banditry situation in state.

5. **Breakdown of traditional conflict resolution mechanisms:** Weakened traditional leadership and a decline in customary dispute resolution processes have contributed to the escalation of conflicts. Nigeria's Security Situation Analysis Report of 2022 by Nextier indicates that: banditry is exacerbated by ethnic differences between the Hausa and Fulani groups in Zamfara. If such differences were quickly addressed by conflict resolution mechanisms, chances are that banditry in Zamfara wouldn't have taken the dimension it has now.

5 Effects of Banditry on Food Security

One of the most pressing issues exacerbated by banditry is food security brought about by the disruption of agricultural activities. This is done in a number of ways, some of which are:

1. **Displacement of farmers**: Banditry has led to the displacement of farmers from their lands. Fear of attacks forces farmers to abandon their fields, leaving crops to wither and harvests unattended. This not only results in immediate economic losses for farmers but also contributes to long-term food insecurity as production levels decline.

2. **Lack of Access to farmlands**: The SB Morgan Intelligence report of 2024 indicates that:

"In Zamfara, bandits have imposed taxes on farmers as an additional means of earning money, in addition to kidnapping for ransom and cattle rustling. To ensure prompt payment, bandits threaten to block access to farmlands and ransack farmers' settlements."

The threat of blocking access to farmlands and ransacking farmers' settlements if taxes are not paid can result in farmers abandoning their lands or being unable to tend to their crops. This disruption in food production can lead to reduced availability of food, exacerbating food insecurity in Zamfara State.

3. **Decreased yields and productivity brought on by financial strain on farmers:** The taxes imposed by bandits create an additional financial burden on farmers, reducing their ability to invest in agricultural inputs such as seeds, fertilizers, and equipment. This financial strain may lead to decreased agricultural productivity and output. This decreased productivity translates into food shortages and higher prices for staple crops, further straining food security in the state.

4. **Disruption of market networks**: Hon. Ibrahim Magaji Dosara (2021) noted that, bandits were able to establish 24 routes network across the 14 local government areas of Zamfara state, with Two Hundred and thirty-two (232) leaders and large followership of Four Thousand, Eight Hundred and Twenty-Five bandits across the state. Through these routes and large followership, these bandits end up disrupting market networks and trade routes, hindering the distribution of food supplies across Zamfara State and beyond. Transporting goods becomes risky and costly, leading to shortages and price hikes in local markets. Additionally, traders may avoid entering areas affected by banditry, further limiting access to essential food items for both rural and urban populations.

5. **Impact on livelihoods:** The pervasive insecurity created by banditry undermines the livelihoods of farmers, traders, and other stakeholders in the agricultural value chain. Small-scale farmers, who form the backbone of Zamfara's agricultural sector, endure most of the impact, facing challenges in accessing credit, markets, and extension services. The resulting loss of income perpetuates poverty and food insecurity in the state.

6 AREA OF STUDY

Zamfara, a state blessed with vast arable land and other natural resources that support agriculture and farming activities, is one the seven states that make up the Northwest geopolitical zone in Nigeria. It was carved out of Sokoto State in 1996 and it shares with Niger Republic and other states like Kastina, Sokoto, Kebbi and Niger. Zamfara comprises of fourteen local government areas, with a land mass of thirty-nine thousand, seven hundred and sixty-two square kilometers

(39,762m2). It has a population of three million, two hundred and seventy-eight thousand, eight hundred and seventy-three 3,278,873 (2006 census figures), and predominately agrarian. Hausas are the dominant tribe while the Fulani form about 25-30% of the total population.

The Zamfara State slogan being 'Farming is our pride' has fertile and arable land that support the cultivation of many crops approximately 80% of the population lives in agricultural produce. The State is blessed with vast forest composed of about thick grazing reserves which covers about two million, two hundred and twenty-five thousand, six hundred and forty-eight hectares (2,225,648Hectares). However, with the emergence of insecurity in the state many investments are discouraged and even stopped from operating.

This research work therefore is an attempt to assess the security situation in Zamfara state and how it affects food production, this is with a view to proffer solutions geared towards achieving increased food production and sustainable peace in the state.

6.1 OBJECTIVES OF THE PAPER
1.   To find out the effect of banditry on food production in Zamfara State?
ii.   To investigate the causes of banditry in Zamfara State?
iii.   To know how effective are security agencies in curbing the activities of Bandits in Zamfara State?
iv.   To present possible solutions to banditry in Zamfara State?

6.2 REASEARCH QUESTIONS
The following research questions were posed to guide the study
1.   Does banditry have effect on food production in Zamfara State?
ii.   What are the causes of banditry in Zamfara State?
iii.   How effective are security agencies in curbing the activities of Bandits in Zamfara State?
iv.   What are the solutions to banditry in Zamfara State?

6.3 RESEARCH HYPOTHESIS
For the purpose of this study, the following hypothesis will be tested:
1. Bandits have no significant effects on food production in Zamfara State.

6.4 SAMPLING PROCEDURE AND SAMPLE SIZE
A four stage sampling technique was used to determine the sample size of the study. In the first stage, one Agricultural Development Project Zone out of the zones was purposively selected for the study due to the high number of farmers in the Zone. Two Local Government Areas (Mafara, Bakura and Talata) were randomly selected. In the third stage, two districts each from the selected LGAs were randomly selected. In the fourth stage, three villages were randomly selected from each of the selected districts and finally, thirty (30) farmers were randomly selected from the villages, giving a sample size of one hundred and eighty (180) respondents for the study.

7 DATA PRESENTATION AND ANALYSIS
Results of data analysis and findings based on research questions taking into consideration the research survey objectives. Results are presented individually in tables according to the order of the research questions and hypotheses.

Table 1: SOCIO – DEMOGRAPHIC CHARACTERISTIC OF THE RESPONDENTS: AGE

Age	Frequency	Percentage
18 – 27	13	7.22
28 – 35	27	15
36 – 43	33	18.33
44 – 51	41	22.78
52 – 59	45	25
60 – 67	14	7.78
68 and above	7	3.89

Total	180	100.0

Source: Research Fieldwork, 2024

Table1 showed that 25% of the farmers were within the age range of 52 – 59 years, 22.78% of them were within 44 – 51 years and 18.33% were within 36 – 43years. 15% were within 28 – 35years. Also, 7.78% were between 60 – 67years and 7.22% of the respondents were in 18 – 27 years. Finally, 3.89% were at age 68 and above.   The mean age reveal that majority of the farmers were in their active and youthful age and hence expected to be energetic and productive age.

Table 2: Gender

Gender	Frequency	Percentage
Male	171	95
Female	9	5
Total	**100**	**100.0**

Source: Research Fieldwork, 2024

Table 2 shows that majority of the farmers were males constituting 95% while 5% were females.

Table 3: What is your level of educational attainment?

Educational attainment	Frequency	Percentage
Adult education	9	5
Primary	29	16.11
Secondary	53	29.44
Tertiary	25	13.89
Qur'anic education	64	**35.56**
Total	**180**	**100.0**

Source: Research Fieldwork, 2024

Results in Table 3 also indicated that **35.56**% of the respondents had Qur'anic education only, 29.44% attained secondary school education while 16.11% of the respondents had Primary education. 5% have adult education, indicating that most of the farmers had one form of formal education or the other.

Table 4: Marital status

Marital status	Frequency	Percentage
Married	157	87.22
Single	15	8.33
Divorced	3	1.67
Widowed	5	2.78
Total	180	100

Source: Research Fieldwork, 2024

Table 4shows that majority (87.22%) of the respondents were married, 8.33% were single, and few (2.78% and **1.67**%) of them were widowed and divorced respectively. The findings indicate that majority of the farmers were married and have family responsibilities to cater.

Table.5: What is your other occupation?

Occupation	Frequency	Percentage
Hand working	88	48.89
Civil servant	33	18.33
Trading	59	32.78
Total	**180**	**100.0**

Source: Research Fieldwork, 2024

Table 5 indicated that 48.89% of the respondents were engaged in hand working; 32.78% were traders while 18.33% were civil servant.

Table 6: Land acquisition

Land acquisition	Frequency	Percentage
Inheritance	91	50.56
Purchased	47	26.11
Rent	33	18.33
Borrowing	9	5
Total	180	100.0

Source: Research Fieldwork, 2024

Table 6 indicated that majority (50.56 %) of the respondents acquired their land through inheritance while 26.11% of them acquired their farmlands through purchase; 18.33% of them through rent and few (5%). through borrowing. According to these findings, most of the farmers possessed their land through inheritance.

Table 7: Farm size(ha)

Farm size (ha)	Frequency	Percentage
0.5-5	123	79.44
5.5 ha and above	57	31.67
Total	180	100.0

Source: Research Fieldwork, 2024

Farm Size: Table7 further revealed that majority (79.44%) of the respondents had between 0.5-5 hectares of the farmland, while few (31.67%) had 5.5 hectares and above. The mean farm size of hectares indicating that majority of the farmers owned small farm.

Table 8: What is your income monthly?

Income	Frequency	Percentage
N0 - N15,000	23	12.78
N16,000 - N30,000	37	20.56
N31,000 - N45,000	35	19.44
N46,000 - N60,000	29	16.11
N61,000 - N75,000	25	13.89
N76,000 and above	31	17.22
Total	**180**	**100.0**

Source: Research Fieldwork, 2024

As shown in Table 8, 20.56% of respondents had monthly income of N16,000 - N30,000 and 19.44% had N31,000 - N45,000. Also, 17.22% of the respondents had N76,000 and above. Meanwhile 16.11% earned between N46,000 - N60,000; 13.89% generated N61,000 - N75,000 and 12.78% earned N0 - N15,000. The modal income category was N16,000 - N30,000.

Table 9: Respondent perceptions on Banditry

Items	Frequency	Percent
They are very destructive	156	86.67
They are Fighting a just cause	3	1.67
They are Fighting the government	2	1.11
They are fanatics with extreme	19	10.56
Total	**180**	**100.0**

Source: Research Fieldwork, 2024

Table 9 shows that most respondents (86.67%) see Banditry as being destructive while (1.679%) of them view the sect as people fighting a just cause. 1.11% of the respondents see them as people who are fighting the government of the day while 10.56% of them are of the view that Bandit are fanatics with extreme views of life.

Table 10 Respondents view on factors responsible for the formation of Bandits

Response	Frequency	Percent
Misinterpretation Religion	8	4.44
Political	2	1.11

Ethnicity	3	1.67
Economic	149	82.78
Corruption	5	2.78
Influence from established terrorist organization	13	7.22
Total	**180**	**100.0**

Source: Research Fieldwork, 2024

Tale 10 indicates that misinterpretation of religion, political factors, ethnicity, economic factors, corruption and influences from established terrorist organization were the major factors responsible for the emergence of banditry.

Table 11: Respondents views on why banditry is existing in Zamfara state

Items	Frequency	Percent
Level of poverty	156	86.67
High level of illiteracy	5	2.78
Closeness to border	11	6.11
Idleness of youths in the region	8	4.44
Total	**180**	**100.0**

Source: Research Fieldwork, 2024

Most the respondents (86.67%) indicated in table 11 that bandit in Zamfara state is influenced by level of poverty in the region; illiteracy (2.78%), closeness to border (6.11%) and idle youths (4.44%). Most of the participant in the key informant interview was of the views that the presence of youths called the Alma-Jiri who has limited or non-western education gave impetus to why there are more bandits.

Table 12: Respondents views on whether or not Banditry could be Eradicated

Items	Frequency	Percent
Yes	167	92.78
No	5	2.78
I don't know	8	4.44
Total	**180**	**100.0**

Source: Research Fieldwork, 2024

Table 12 shows that over three quarter of the respondents (92.78%) are of the opinion that banditry could be eradicated, while 4.44% of them did not agree that it could be stopped. Also 4.44% of them stated they do not know whether or not banditry could be eradicated from the country.

Table 13: Respondents views on impacts of banditry on socio-economic development of Zamfara state

Items	Frequency	Percent
Fluctuation of economic activities	65	36.11
Low investments and low patronages	19	10.56
Low inflow of customers from neighboring towns and cities	48	26.67
Fear of poisonous food	15	8.33
Reductions of goods in markets	17	9.44
High cost of available few goods in markets	16	8.89
Total	**180**	**100.0**

Source: Research Fieldwork, 2024

Table13 shows that 36.11% of the respondents believed that banditry reduces the inflow of customers from neighboring states and towns; while (22%) of the respondents view that commercial activities are no more stable, while (12%) admitted that goods and services in the markets reduces drastically. Furthermore, (8%) said that little available goods in markets become very costly where the poor cannot afford. (5%) of the respondents agreed that people no longer go to buy goods because of the fear of poisonous food by the while (4%) of them responded low investors and low patronage.

Table 13: Respondents views on ways of stopping the activities of bandit

Items	Frequency	Percent
By using military action against them	156	86.67
By negotiating with them (Bandits)	5	2.78
By creating employment in the region	8	4.44

By giving orientation to the Bandits	6	3.33
By policing the borders effectively	5	2.78
Total	**180**	**100.0**

Source: Research Fieldwork, 2024

The respondents view in table 13 shows that almost half of the respondents (86.67%) believed that military action should be used against the bandits; 2.78% of them advocated for effective policing of the borders while 3.33% of them maintained that re-orientating the bandits is what is needed to curb the activities of the bandits, furthermore, 2.78% of the respondents are of the opinion that government should negotiate with the bandits.

8 HYPOTHESIS TESTING

This section deals with the analysis and interpretation of hypotheses of this study. Statistical Package for Social Sciences (SPSS) application was used to calculate the Chi-square (χ^2) statistic to test the hypotheses. The level of significant used in the analysis is 5% (i.e. 0.05). The decision rule is that if p-value is greater than 0.05, we accept the null hypothesis (H_0) and conclude that there is no significant relationship between the variables. On the other hand, if p-value is less than 0.05, we accept the alternative hypothesis (H_i) and conclude that there is a significant relationship between the variables. The hypotheses are as follow:

HYPOTHESIS
H_0:   Bandits have no significant effects on food production in Zamfara State.
H_i: Bandits have significant effects on food production in Zamfara State.

Table 14: Statistical Package for Social Sciences (SPSS) Calculated Chi-square (χ^2) Results

To what extent do you agree with the following statement: "I believe that Bandit is a significant threat to farming activities."	What is your Occupation?			
	Hand working	Civil Servant	Trading	**Total**
Agree Strongly	41	17	7	65
Agree Moderately	27	9	12	48
Agree Slightly	11	3	5	19
Disagree Slightly	3	9	3	15
Disagree Moderately	2	4	11	17
Disagree Strongly	3	1	12	16
Total	87	43	50	**180**
χ^2= 62.58a DF=10 P-value=0.001				

Source: Research Fieldwork, 2024

In the table above, since p-value (0.001) is less than the level of significant (0.05), we will accept H_i and conclude that

the activities of Bandits have significant effects on socio-economic development of Zamfara state.

9 Recommendations
Tackling banditry in Zamfara State requires a comprehensive approach that addresses both the immediate security concerns and the underlying socioeconomic factors contributing to the problem. Here are some recommendations:
1. **Sensitization programmes on the negative effects of banditry:** The government should commence a radical sensitization programme across the affected states to dissuade young people from joining or enabling bandit activities (Nextier, 2024). Such a senitization programme will help educate young people on the negative effects of banditry.
2. **Strengthen security measures:** Security measures must also be improved upon in Zamfara State. There must be an increased security presence to deter criminality, more intelligence gathering and inter-agency collaboration to curtail the social problem of banditry. The government should also reform the security apparatus with an emphasis on increasing the size, funding, training, intelligence, support, and communication equipment of security forces (Akinyetun, 2022).

3. **Stakeholders collaboration**: Collaboration with relevant stakeholders can play a crucial role in curbing banditry in Zamfara State by leveraging their expertise, resources, and influence to address the multifaceted nature of the problem. Both primary and secondary stakeholders like the community, security agencies, traditional leaders, politicians, government and NGO should focus on providing information for early warning; organize training, workshop and seminar on peace building processes and reconciliations. Promises made during such gatherings should be respected and redeemed (Sanchi et'al, 2022).

4. **Tackling socio-economic issues**: Addressing socio-economic issues like poverty and unemployment is crucial for curbing banditry in Zamfara State because these issues are often root causes or contributing factors to the emergence and perpetuation of banditry. Government at all levels should come up with credible and implementable people-oriented policies and programmes to address the basic livelihood problems of poverty, unemployment and the like (Hannatu, 2022).

10 Conclusion

Banditry poses a significant threat to food security in Zamfara State, exacerbating existing challenges and undermining the well-being of its residents. Addressing this complex issue requires a multifaceted approach that combines security measures with efforts to support agricultural livelihoods, strengthen market systems, and promote resilience among vulnerable populations. By addressing the root causes of banditry and investing in sustainable solutions, Zamfara State can work towards a future where all citizens have access to adequate food.

The effects of banditry on food security in Zamfara State extend beyond immediate disruptions. The cycle of violence and instability hampers investments in agriculture, discourages youth engagement in farming, and erodes the resilience of communities to withstand future shocks. Without effective intervention, the vicious cycle of banditry and food insecurity threatens to perpetuate poverty and instability not just in Zamfara State alone but the entire country.

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Conflict stabilization measures in the Nigeria's North East: A Bottom-Top Approach and Lessons Learnt for Effective local-level Involvement.

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Abstract

Fighting insecurity in a country like Nigeria poses a significant challenge due to inadequate modern infrastructure and low levels of awareness in many areas. These shortcomings, coupled with the silence in some communities, greatly hinder efforts to confront bandits, kidnappers and armed actors in the polity directly and effectively implement non-kinetic approaches. Since 2009, the Boko Haram insurgency and the government's military response have killed tens of thousands of civilians and displaced millions across the Lake Chad region, which links Cameroon, Chad, Niger, and Nigeria. Although major military campaigns in 2015–2016 succeeded in degrading the group's territorial control, Boko Haram has proven remarkably adaptable in its tactics: the end of 2018 once again saw an uptick in attacks in Nigeria's BAY States. As Bola Tinubu assumes his first term as president, the conflict in the northeast appears far from resolved. Though the administration has made gains, but more still need to be done. Since the early years of the crisis, Nigeria's international partners have cautioned that Boko Haram is unlikely to be defeated on the battlefield alone. They have stressed the need for a multidimensional response that tackles the drivers of insecurity in the region, including chronic weaknesses in service delivery, corrupt governance, and environmental degradation. However, the perception of limited leverage over Nigerian counterparts, restricted access to the country's northeast, and a response to the crisis shaped by the U.S.-led Global War on Terror limited donors' focus on these governance dimensions on the ground. This is the thrust of this paper. Using documentary methods and the technique of content analysis this paper provides an overview of these local-level efforts and the theories of change that underpinned them. It highlights initial lessons learned by donors and implementers of the programs. The study observed that the stabilization programs were designed with the assumption that the security situation in northeastern Nigeria would continue to improve, thereby facilitating the gradual return of displaced populations and local government. Yet in practice, Nigeria's overstretched, under-resourced, and corruption-plagued military has struggled to consolidate its gains. Civilians in many parts of the northeast face ongoing threats from both insurgent attacks as well as counterterrorism operations. The paper recommends among other that strengthening local security mechanisms and restoring civilian administration and basic services are critical, the paper conclude**s.**

Keywords: Insurgency, Stabilization Programmes, BAY states, Bottom- Top Approach and Security challenges

1 Introduction

The Boko Haram insurgency has caused untold devastation in the North-east Nigeria. Since 2009, it is estimated that over 25,000 people have been killed and over two million displaced. In North-East Nigeria, where 80% of the people rely on agriculture for their livelihood, the economic impact has been brutal, with farmers forced from their land, livestock killed, stolen and continued insecurity preventing a safe return in many areas.

As a first step, the Nigerian government asked the World Bank in August 2015 for help in assessing the damage and corresponding needs in the North-East. An empirical evidence base and reliable data are critical for informed decision making, as the government moves forward not only to fix the brick and mortar, but to mend the hearts and minds that have been hurt by the violence. In response, a joint team of the World Bank, the European Union (EU), and the United Nations (UN), working closely under the government's leadership, initiated the North-East Nigeria Recovery and Peace Building Assessment (RPBA), a comprehensive analysis of damages and estimated needs resulting from the Boko Haram crisis. It began with a comprehensive conflict analysis that served as the backbone of the assessment, including the underlying drivers to provide an integrated approach to peace building and recovery.

The RPBA covered the six most affected states in North-East Nigeria: Adamawa, Bauchi, Borno, Gombe, Taraba, and Yobe. Collecting data in six states across twenty sectors was challenging, particularly given the sensitive security environment that prevails in some areas. Where information was scarce or areas inaccessible, we relied on remote sensing technology, a combination of satellite imagery, social media analytics and information received from partner networks (World Bank, 2016).

It was encouraging to see then Nigerian President Muhammadu Buhari highlighting the importance of post-conflict recovery and reconciliation. The communiqué issued at the close of LCBC summit encouraged Nigeria to set up *"a Coordinating Mechanism for the post-conflict rehabilitation and development of the North East region of Nigeria based upon the findings of the Recovery and Peace Building Assessment"* with the assistance of United States, United Kingdom, France, EU and the World Bank.

Another feature of this assessment was that it was done while violence was still ongoing in parts of the region. Given the urgent needs on the ground, the assessment was concluded within 3 months. It was a rewarding experience, to work together with partners – EU, UN, and the Federal, State and Local governments – towards a common goal. Early, coordinated and rapid engagement from multiple partners also helps to bridge the gap between critical life-saving humanitarian assistance, and sustainable and durable solutions to impacts of conflict and forced displacement.

The findings by the LCBC was to be used by Federal, State and Local governments as well as partner organizations to develop stabilization and recovery plans. Given the complex context, sequencing the recovery and peace building interventions is essential to ensuring a realistic response to the crisis. The LCBC adopted this document. This paper considers the ways in which knowledge and research influenced the design of a programme to reduce violent conflict in Nigeria using the North-east as a case. The diversity of sources and forms of conflict in Nigeria, and the way that local grievances interact with national struggles over politics and resources, combined with a need to show measurable results within fourteen years, made the task of programme design extremely challenging. The article discusses how the project design team responded to this challenge. It describes the four main lessons that emerged from dialogue-based research studies that helped the design team formulate a theory of change for the programme, and subsequently its methodological approach and activities. The studies shaped the central theme of the project, which was the need to transform conflict management institutions into genuinely inclusive forums for dialogue, thereby regaining the trust of those currently excluded from dialogue but yet most affected by violence – particularly unemployed youth and women and girls.

The first part of the article addresses the fundamental question of terminology: how do we 'label' – and hence signal in a way that leads to appropriate action – a programme that is directed at reducing conflict? Section two goes on to map the approach taken by the team in the design of the programme. In particular, early research, in the form of a broad set of inception studies on the incidence and causes of conflict and mechanisms for managing it, led to the development of a diagnostic typology of types of violent conflict. It also led to a number of key conclusions about conflict and violence in the project zones that were important in shaping the design of the programme. Also highlighted in the article is the consultative approach taken by the team to programme design, during which over 1,200 ordinary people, as well as leaders in public and non-governmental bodies, were consulted.

1.1 Stabilisation

The term stabilization is widely used in Western political debates and military and strategic doctrines, but its meaning remains ambiguous as it is often applied to widely diverging activities. To pursue some more conceptual clarity, we start out by exploring the etymological roots and the current usage of the term in various doctrinal publications.

Linguistically speaking, the word stabilization comes from a proto-Indo-European root *sta-, which meant 'to stand, set down, make or be firm'. We know many variants of this word such as the English verb '*to stand*' (or also Dutch words like '*staan*', '*stand* ', etc.) or even 'place or thing that is standing' (e.g. the Persian -*stan* 'country', literally 'where one stands'; or the Dutch word '*stad* '). All of these cognates seem to refer to a condition in which an object or subject stands firm – in contrast to a condition in which it might fall or has fallen. Stability is generally seen as a desirable condition, although many scholars have also pointed out that a stable but undesirable condition is not something that should be pursued in its own right. Stabilization, then, refers to the active pursuit of the condition of stability (Spiegeleire,Sweijs, Wijninga and Esch, 2014). The authors went further to posited that;

The term stabilization is a familiar term in many different walks of life today. For *medics,* stabilize a patient before transporting her to the nearest-by medical facility; *economists* talk about economic stabilization as with the bailout of the U.S. financial system after the subprime mortgage crisis; *photographers* stabilize their cameras to prevent the effect of shaking the image; *construction teams* often stabilize buildings when they are afraid of structural collapse; *airplanes* have both vertical and horizontal stabilizers to keep the planes steady in the air; in *chemistry*, stabilizers are chemicals that tend to inhibit the reaction between two or more chemicals; and in *electricity* stabilization refers to devices that automatically maintain a constant voltage. Already in these contexts, we find back a number of important differences in the way in which stabilization is defined that we will also find back when we turn our attention to stabilization in a security context (Spiegeleire, Sweijs, Wijninga and Esch, 2014, p.1).

These scholars also went further to observe that these same differences in what stabilization actually entails can also be found back in the discussions about stabilization in the security and defense realm. In common defense parlance today, stabilization is generally used to refer to the immediate post-conflict phase in a militarized conflict. This is typically

thought to occur after military intervention in a period. Efforts when there may still be a considerable amount of violence, and before actual normalization. Stabilization is thus said to be the phase in which basic order has to be/is being restored and preparations are made for long-term reconstruction.

The US started using the term in the early 2000s to refer to a wide range of activities which were previously called peace support operations. Most Western states have since included the term stabilization in their military doctrines. But the term still has clearly has different meanings and refers to all sorts of different activities and definitions of stabilization. Some states use it to denote a grand strategy for the establishment of sustainable peace, whereas others only focus on the military contribution to so-called stability operations. States have different views on the short-term and long-term objectives, the actors, the level of violence or the duration and the timing of stabilization efforts.

In the United Kingdom, the term stabilisation has acquired specific meaning through implementation on the ground: western military and civilian involvement in Afghanistan and Iraq since 2002/3 has consistently described its aim as 'stabilisation'. The UK's approach to stabilisation is set out in guidelines issued jointly by three government departments: The Ministry of Defence (MoD), the Foreign and Commonwealth Office (FCO) and the Department for International Development (DFID). These represent the military, diplomatic and development interests typically taking part in stabilisation operations. (Stabilisation Unit Guidance Notes, November 2008).

The UK government guidelines broadly reflect US and EU usage.
From the above, the UK usage of the term stabilisation is similar to that in the US. As one US analyst describes it: 'Stabilization and reconstruction (S&R) operations primarily concern the funneling of western taxpayers' money into ungoverned spaces through the medium of military and civilian efforts, in partnership with the people therein, in pursuit of mutual security'. (Lindley-French 2009: 1).

There is an ongoing debate about the usefulness, ethics and efficacy of stabilisation interventions as they have been applied in countries such as Iraq and Afghanistan (See, McNerney 2005). Several studies examine the efficacy of aid interventions to 'win hearts and minds' within stabilisation interventions and find them wanting. This is mainly because the causes of violent conflict are at base political and neither military force nor the provision of basic services tackles the underlying political causes (Dennys 2013, Fishtein and Wilder 2012).

They and other commentators broadly agree on the meanings ascribed to the term 'stabilisation' and what sets stabilisation apart from humanitarian and development work. These distinctions include the following:
Stabilisation interventions have an explicit *political agenda* and neither aim nor claim to be politically neutral. A primary aim is to help establish and sustain a government that can be supported to govern effectively and fulfil its core functions, particularly security. Stabilisation interventions by foreign powers may involve regime change or the bolstering of existing regimes.

Stabilisation normally describes a *joint military and civilian effort*. Because force is normally an essential component of stabilisation, the military tends to take the lead, at least initially. In parallel or subsequently, diplomatic interventions are used to support political processes (e.g. elections), and development projects (justice, infrastructure, education, etc.) to build support for the government and lessen the backing of militants.

Since the early years of the crisis, Nigeria's international partners have cautioned that Boko Haram is unlikely to be defeated on the battlefield alone. They have stressed the need for a multidimensional response that tackles the drivers of insecurity in the region, including chronic weaknesses in service delivery, corrupt governance, and environmental degradation. However, the perception of limited leverage over Nigerian counterparts, restricted access to the country's northeast, and a response to the crisis shaped by the U.S.-led Global War on Terror limited donors' focus on these governance dimensions on the ground. In practice, international assistance came late and donors struggled to identify viable national counterparts for stabilization programs. As a result, their efforts centered on supporting regional military efforts and responding to the large-scale humanitarian crisis.

Since early 2017, military gains and improved security in parts of northeastern Nigeria have spurred a greater focus on conflict stabilization measures. At the international level, key donors set up the Oslo Consultative Group on the Prevention and Stabilization in the Lake Chad Region to coordinate their response activities. The Lake Chad Basin Commission and the African Union Commission have adopted a regional stabilization strategy, which highlights short-, medium-, and long-term stabilization, resilience, and recovery needs.2 In parallel, donors have also begun expanding bottom-up stabilization programs aimed at addressing the drivers of insecurity at the local level. These efforts have generally fallen into three main categories: programs aimed at strengthening local conflict prevention and mitigation systems, programs aimed at restoring local governance and basic services, and programs aimed at fostering social cohesion and ensuring the reintegration of former combatants. Central to this is the concept of a stable governance.

USIP adds that stable governance refers to an end state where the state provides essential services such as security and basic essential services serve as a responsible steward of state resources; government officials are held accountable through political and legal processes; and the population can participate in governance through civil society organizations, an independent media, and political parties. Stable governance is the mechanism through which the basic human needs of the population are largely met, respect for minority rights is assured, conflicts are managed peacefully through inclusive political processes, and competition for power occurs nonviolently. National and subnational government institutions may work with a range of non-state partners to provide some of the government functions.

Stabilisation interventions are not primarily motivated by development concerns such as poverty or human rights violations but by assessments of *national and regional interests* by the countries sending troops and civilian personnel. Decisions to intervene may be based on the threat of terrorism, military and economic interests, or large-scale migration as well as regional threats and opportunities. Historical/colonial links may also play a role.

These characteristics indicate significant differences between 'stabilisation' as the term is currently being used in western countries and the types of conflict prevention or peacebuilding interventions funded mainly by development budgets. The most obvious difference is that interventions funded through development aid are not associated with military intervention. However, in other respects, we need to acknowledge that the differences are not absolute. It can certainly be argued that humanitarian and development interventions are not politically neutral, and that donor funding is not devoid of self-interest. It is also worth noting that development actors play a part in stabilisation campaigns. Thus the line between stabilisation and development interventions in conflict-affected countries may be less clearly drawn than it initially seems(6)

That said, the term stabilisation is scarcely applicable to efforts to address Nigeria's current crises. The various Joint Task Forces (composed of Army, Navy, Air-Force, Police and State Security Service personnel) stationed in different parts of the country (notably the North East and Niger Delta), and the emergency rule periodically imposed by the federal government, might be described as internal attempts to 'stabilise' regions experiencing violent conflicts. However, there has been no joint foreign military and civilian effort to address current crises. In short, the situation in Nigeria is not one of 'stabilisation' in the sense in which the term is currently used and applied.

Specifically, the essential characteristics of a stable governance include:

- *Provision of Essential Services* is a condition in which the state provides basic security, the rule of law, economic governance and basic human needs services; essential services are provided without discrimination; and the state has the capacity for provision of essential services without significant assistance from the international community.
- *Stewardship of State Resources* is a condition in which national and subnational institutions of governance are restored, funded, and staffed with accountable personnel; the security sector is reformed and brought under accountable civilian control; and state resources are protected through responsible economic management in a manner that benefits the population.
- *Political Moderation and Accountability* is a condition in which the government enables political settlement of disputes; addresses core grievances through debate, compromise, and inclusive national dialogue; and manages change arising from humanitarian, economic, security, and other challenges. A national constituting process results in separation of powers that facilitates checks and balances; the selection of leaders is determined through inclusive and participatory processes; a legislature reflects the interests of the population; and electoral processes are free and fair (USIP).
- *Civic Participation and Empowerment i*s a condition in which civil society exists and is empowered, protected, and accountable; media are present, professional, and independent of government or political influence; equal access to information and freedom of expression are upheld; and political parties are able to form freely and are protected.

Having considered, and for the moment put aside, the relevance of the term 'stabilisation' for conflict programming in Nigeria, we now ask how pertinent are the other two terms considered here – 'stability and reconciliation' and 'peacebuilding'. What is their genesis and how applicable are they to the Nigerian context? This question will be answered later

2 Theoretical Framework of Analysis

A bottom-up approach is a strategy used across various fields, including management, security sector, software development, and project planning, where the process begins at the most detailed and basic level and works upwards to

form a comprehensive picture or solution. Bottom-up usually refers to **citizen-led activities where citizens collaborate and themselves keep control of the aims, the means, and the actual implementation of their activities** (Healey 2015). The initiatives are often rooted in some form of dissatisfaction with the current situation, a perception of inability, inaction, or sluggishness of public actors in responding thereto, and a desire to tackle the issue at hand (Van Eijk & Steen 2016).

Bottom-up initiatives can also be a trigger for larger processes of transformative change; some protest movements can be seen as bottom-up. As a result, bottom-up activities affect not only other citizens, but also tend to imply some sort of pressure put on 'those above'. These are typically political representatives, but could also be, for example, companies or international organisations.

Bottom-up is therefore also used in opposition to the concept of 'top-down', which refers to something being enacted or enforced by authorities. More broadly, it also means that citizens create spaces of participation themselves, instead of being invited into spaces of participation by, for example, government actors. Nonetheless, bottom-up initiatives often include – or gradually develop – links to formal institutions like local authorities, NGOs, and governmental authorities (Eckerberg et al. 2015).

Western financial aid by using the top-down approach has not been successful when compared to the results of poverty reduction programs in poor Underdeveloped countries over the past decades. As a result, bottom-up institutions like NGOs and bottom-up development programs like microfinance emerged in the late 80s and have become popular across developing countries. However, recently, the performance of NGOs has been questioned and it is perceived that they have lost their roots. Moreover, the bottom-up NGOs seem unable to flourish further without financial aids although bottom-up development approaches seem to be more effective than top-down development approaches as they ensure people's participation and right to choose. Bottom-up approaches are very common and often highly impactful, especially in relation to environmental and security problems and social inequalities.

2.1 Tenets of the Theory

The theory has the following tenets:

2.1.1 Collaboration

When approaching project objectives from the bottom up, a team will collaborate across all levels to determine what steps need to be taken to achieve overall goals. The bottom-up approach is newer and more flexible than the more formal top-down strategy, which is why it's more commonly found in industries where disruption and innovation are a priority.

2.1.2 Democratic management

Leaders work with team members to determine what decisions should be made at each level, allowing for better collaboration while also maintaining structure. The bottom-up style of management solves many of the problems that come with the top-down approach. This approach has advantages that make it a great fit for creative teams and institutions where collaboration is key, like security, software development, product design, and more.

2.1.3 More informed decisions

In collaborative settings, those who work directly on projects and oversee project management can speak to the decisions that will impact their future work. Upper managers work directly with team members to chart a course of action, which prevents potential process blind spots that might otherwise appear when decisions are made without team input.

2.1.4 Better team morale

The bottom-up approach encourages greater buy-in from team members because everyone is given the opportunity to influence decisions regardless of seniority. It also facilitates better relationships between and among colleagues by offering members of all seniority levels an equal opportunity to influence project outcomes. In doing so, this approach increases the likelihood that all members will be invested in the team's success.

2.1.5 More room for creativity

In top-down processes, there are fewer opportunities for teams to give input or suggestions. Collaborative approaches like the bottom-up approach, on the other hand, create opportunities for feedback, brainstorming, and constructive criticism that often lead to better systems and outcomes.

Among the disadvantages of this approach include that it reduces momentum. This is because when everyone in a group is invited to collaborate, it can be harder to arrive at a decision and, as a result, processes can slow down. It

also shifts team dynamics. Though it is relevant to give team members the opportunity to provide feedback, not everyone is comfortable doings.

2.2 Application of the Theory to the Study

According to Operational Guide for Community Stabilization Programmes and Approaches (2019) and IOM's Operational Guide: Community Stabilization Programmes and Approaches (Internal Link, 2024), as crises have become increasingly recurrent, protracted and multidimensional, there has been growing recognition that, while humanitarian assistance and protection remains critical, it is on its own insufficient to sustainably reduce needs, risks and vulnerabilities. Development and humanitarian crises are inter-related, with development deficits underpinning or exacerbating the humanitarian impacts of crises, and humanitarian crises in turn disrupting – in some cases, reversing – progress toward the achievement of the Sustainable Development Goals (SDGs).

In view of these issues, in fragile, transitional and/or crisis-affected contexts, Community Stabilization (CS)programming can help to address the drivers of instability in order to prevent or mitigate conflict and displacement. Unlike development programming, CS programming does not tend to address the root causes of crisis, but rather to mitigate the immediate drivers of crisis or conflict, in order to stabilize communities. As stabilization is often a precondition to development programming to address the root causes of crisis, CS can be seen as a "bridge" between humanitarian and development interventions.

Consequently, in IOM, CS programmes are sometimes referred to as addressing 'the missing middle'. CS is an objective or outcome, as well as a process, which employs specific methodologies. While the tools used in CS programming may be familiar (e.g. livelihoods, health, WASH, education or community infrastructure interventions), it is *why* these tools were selected and *how* these tools are used which determines whether a programme constitutes CS. For example, while humanitarian assistance is needs-based (e.g. IOM may rehabilitate a primary health center (PHC) because communities do not have access to essential health services), stabilization programmes prioritize activities which address the drivers of crisis or conflict (e.g. IOM may rehabilitate a PHC because the strain on health services is creating tension and undermining confidence in the local government in a particular community).

Principles and methodologies applied in IOM's CS programming aim to maximize its impact in addressing drivers of crisis and conflict. In particular, CS programming places a strong emphasis on community ownership and participation and government leadership and visibility – often, in CS programming, IOM works in the background to support the local government partners to respond to local needs and concerns, and tries to avoid the perception that an international organization is delivering assistance or services which the government should ultimately provide. CS programming is also context-driven and because contexts are not static, it needs to be flexible and adaptable to respond to emerging risks and capitalize on new windows of opportunity.

IOM Community Stabilization programmes operate at the local level to build stability from the ground up and take advantage of IOM's presence and relationships in the field. The broad array of stakeholders targeted include those with capacities to have a transformative impact on unstable contexts. In displacement-prone and displacement-affected areas, CS programming can play an important role in preventing displacement, as well as act as a stepping-stone toward the resolution of displacement.

Before embarking on their stabilization policy, both Nigerian state and multilateral agencies and countries did not take Boko haram as a serious challenge but focused on the Nigeria delta, Iraqi and Syria among other international crises. Scholars such as (Thurston, 2017, Cole, et al.,2017 ICG, 2016, 2018 and Anyadike, 2018) have offered reasons for this situation. For instance, the donor community on the ground in Nigeria was late to acknowledge the severity of the crisis, and slow to scale up its response. Several factors explain this pattern. First, in the early years of the crisis, international partners were hesitant to push back against Nigerian authorities' assurances that the conflict response was under their control. In contrast to other conflict-affected states, the Nigerian government wields significant resources and regional power, resulting in a greater stature vis-a-vis international partners. Donor governments thus prioritized working through Nigerian government structures rather than sidestepping local authority, even as bureaucratic obstruction, a lack of committed interlocutors, and in-fighting between different levels of government slowed down the response (Edwards, 2017).

Second, donor states and the United Nations (UN) had little political interest in declaring the region a large-scale emergency, which would have required additional commitments of resources in an already crisis-ridden international context.(For example, in 2014–2015, UN leadership in the country did little to press for greater international involvement, despite evidence of worsening conditions in the northeast. Western capitals, already preoccupied with crises in Iraq, South Sudan, and Syria, in turn saw Nigeria as a resource-rich country with less need for international aid Edwards, 2017 and

Lanzer,2017).Those donors already present in Nigeria prior to the crisis had mostly specialized in development programs in areas such as health and education, which often relied on close collaboration with Nigerian authorities. Few had a direct presence in the northeast, and those that did worked via partnerships with smaller local groups. However, the scale of these efforts was far below the level of need (Lanzer,2017) These dynamics further delayed the transition to a comprehensive conflict response (McIlreavy and Schopp,2017).

Lastly, the deteriorating security situation and lack of communication lines with Boko Haram limited access and made it difficult to obtain accurate assessments of the rapidly evolving crisis. Beginning in 2013, the state of emergency in Borno, Yobe, and Adamawa States severely restricted mobility and communication flows in the region. Even as the military began pushing Boko Haram into retreat in 2015, continued insecurity prevented the return of civilian administration, and access beyond Maiduguri remained tightly controlled by the Nigerian military(Edwards andRoberts,2017).Despite this difficult context, several donors launched small-scale peacebuilding and countering violent extremism (CVE) programs in the northeast, generally centered on Maiduguri. Yet persistent security concerns and access restrictions prevented a rapid scale-up.

Keeping these issues at the heart there was a change of heart in stabilizing the region in 2016 when donor agencies started pumping denotations into the region. Their response generated mix reactions. While the Humanitarian aid organizations working in Nigeria have argued that it comes too soon, noting that the conflict is still ongoing and hundreds of thousands of people remain beyond the reach of basic emergency assistance. They fear that the language of stabilization is playing into the hands of Nigerian authorities who are eager to emphasize a return to normality and a shift to long-term development assistance while downplaying ongoing crisis conditions. Over the past year, for example, Nigerian authorities have pushed aggressively for displaced civilians to return to their home communities, while Buhari has repeatedly declared that Boko Haram has been "technically defeated." Humanitarian actors warn that a change in donor priorities may lead to aid being allocated based on the Nigerian government's political priorities rather than civilian needs, thereby leaving vulnerable groups without assistance (Buhari, 2016). In northeastern Nigeria, donor-funded local stabilization programs have centered on the following priorities:

- strengthening local- and state-level conflict prevention and community security mechanisms to help communities prevent and solve emerging conflicts and tensions;
- rehabilitating civilian infrastructure and basic services to strengthen government legitimacy and responsiveness to citizen needs; and
- supporting the reintegration of former fighters, civilian militia, and those associated with insurgent groups, as well as local-level social cohesion more broadly, with a long-term view toward social healing and reconciliation (Brechenmacher ,2019)

As observed by (Brechenmacher, 2019), while these three categories and the associated theories of change he outlined do not capture the full range and nuances of existing programs, they reflect the dominant approaches among major international donors—which, in northeastern Nigeria, include France, Germany, Japan, the UK, the United States, and the European Commission. In practice, programs often combine multiple types of interventions and theories of change within a larger package, based on the idea that coordinated support will result in greater stability and resilience to external threats. Table 1 reviews these activities in greater detail. It does not include the wider set of early recovery and CVE interventions that do not have direct links to local-level political processes, though it recognizes that these efforts are often interlinked on the ground.

Table 1: Programs and Related Theories of Change

Type of Program	Theories of Change
Strengthening local conflict prevention and community security mechanisms	Supporting communities to articulate their security concerns and needs to government and security officials will improve early warning and response mechanisms, build greater trust in security forces, and strengthen coordination among security actors at different levels of governance.
	Restoring basic local government presence and basic services will help foster greater citizen trust in government and improve perceptions of government responsiveness.
Restoring local government and basic services	Involving citizens in decisionmaking around local services and development priorities will foster greater social cohesion within communities, build local demand for better governance, and push government officials to be more attuned

Table 1: Programs and Related Theories of Change

Type of Program	Theories of Change
	and accountable to citizen needs.
	Offering targeted services and interventions to at-risk communities and individuals will make them less vulnerable to extremist recruitment.
Supporting reintegration and social cohesion	Ensuring individuals previously associated with nonstate armed groups are accepted back into their families and communities and that local conflicts are resolved peacefully will foster reconciliation, incentivize further defections, and prevent a return to violence and criminality.

Source: Brechenmacher(2019) The above theses will be used to elaborate more on the issue under study.

3 Study Area and Methods of the Study

3.1 Study Area

The political zone referred to as North-Eastern Nigeria comprises of the present states of Adamawa, Bauchi, Borno, Gombe, Taraba and Yobe. Among the prominent factors that make an area a unit of historical study are its geography and human activities. This area shares various geographical, economic, social and political features. The area which constitute North-East zone of Nigeria lies between the vast arid expanse of the Sahara and the dense tropical rain forest along the Guinea Coast. Delimiting the area is Cameroon on the east, Niger and Chad republics on the north, North-Central Nigeria on the west, and South-Eastern Nigeria on the south. It has a total of 103,639 square miles, representing 29.1 per cent of the total area of Nigeria. Interestingly the region is politically unique in its pre-colonial set up. This could be seen it is combination of the Kanem-Borno Empire in the northern part and the Sokoto caliphate controlling most of the southern part. Bornu-Kanem Empire converted to Islam before any other part of what is now Nigeria, and is the one section of the North that withstood the Sokoto jihad of the nineteenth century.

The north-east came into existence on May 5, 1967, when, in his bid to check the influence of Odumegwu Ojukwu in the east, Yakubu Gowon created 12 states out of the four regions in the country. On February 3, 1976, Murtala Ramat Mohammed divided the monolith northeastern state into three – Borno, Bauchi, and Gongola states. This geographical area constitutes the largest zone in Nigeria and comprises of the present states of Adamawa, Bauchi, Borno, Gombe, Taraba and Yobe since the state creation of 1996. This section shall concern identify the varying and important roles these features played in the historical process that brings the different social groups of the area together as north east. The pictogram below captures the political map of the zone.

Fig 1:Map of North Eastern State of Niger

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Source: Google Maps

3.2 Methods of the Study

This study is a descriptive study. What the foregoing implies is that the recourse to the secondary sources of data is inevitable. (Obasi,1999) submits that secondary data refers to any documented material (whether hand written, typed, printed or recorded audio and video) that was already in existence, produced for some other purposes than the benefits of the researcher. Reliable and expressive documents are capable of bringing the significant information, which cannot be obtained through other methods. The issue is that where reliable documents exist, generalizations appear more reliable than those emanating from the limited data of other instruments. Finally, another justification is that this method will assist us to collect data stored in files, government achieves, libraries, bookshelves/shops, the internet and other documents. This study, therefore, utilized secondary sources of data from the Federal Government and its agencies including NEMA, and International Agencies reports such as AI, NSRP, UNDP, NEDC, IOM, HRW, ICG among others. In addition, textbooks, journal articles, newspapers and magazines served as sources of data for the study.

The technique of content analysis is to use for our analysis. It is used to describe events as they are recorded. Bodgan and Biklen (1982:p.145) defined qualitative data analysis as "working with data, organizing it, breaking it into manageable units synthesizing it, searching for patterns, discovering what is important and what is to be learned, and what to tell others". Simon (2011) points that qualitative researchers tend to use inductive analysis of data, which means that critical themes emerge out of the data. Simon (2011) further points that qualitative analysis requires some creativity, since the challenges to place raw data into logical, meaningful categories; to examine them in holistic fashion; and to find a way to communicate this interpretation to others.

4 Boko Haram Crisis: overview

According to (https://humanitarianaction.info/plan/1190/article/nigeria-1),fourteen years into the conflict, the humanitarian crisis in north-east Nigeria remains profound and widespread. Across Borno, Adamawa, and Yobe (BAY) states, over 7.9 million people face severe protection concerns, extreme deprivation beyond their existing poverty levels, and daily threats to their well-being.

From the document still, while the number of people in need has decreased from previous years, the severity and complexity of the needs of affected people has not diminished. Vulnerabilities differ based on location, age, and displacement status, and the interplay of the main drivers of the crisis (conflict and insecurity, the impact of climate change, disease outbreaks, food insecurity and malnutrition, population movement and camp closures, economic factors, and historical underdevelopment). Children, particularly girls, remain the most affected, together with women they make up 83 per cent of those in need. Borno is the most affected state, with more than half the people in need —3.8 million. Adamawa and Yobe follow with 2.1 million and 1.7 million people in need, respectively(https://humanitarianaction.info/plan/1190/article/nigeria-1)

The nature of conflict has changed in the last two years, with fewer attacks on military and government installations. Worryingly, attacks on civilians by non-state armed groups are increasing, particularly in Borno where 1,025 and 1,045 security events were recorded in 2021 and 2022 respectively.

As a result of the evolving security situation and other developments, the number of people in need may have improved in some sectors in Yobe and Adamawa states, resulting in opportunities for recovery and development efforts. In these two states, more can be done to support the Government in restoring basic services and shelter for conflict-affected people and driving solutions for displaced people. In Borno, specifically in Maiduguri, there are opportunities for

identifying solutions for conflict-affected people, including the displaced, as part of urban development efforts, precarious humanitarian needs related to food insecurity and malnutrition remain high in other areas of the state. In Borno and areas in Yobe and Adamawa, conflict continues with severe protection concerns and limited opportunities for recovery and development. High numbers of people with severe needs require a continued emergency response at scale.

Operational challenges persist and still has implications. The persistent conflict and insecurity have severed people from their primary livelihoods, notably agricultural activities. Those who venture outside the protective trenches surrounding the population centres in many parts of Borno are at risk of being killed, maimed, kidnapped or subjected to sexual and gender-based violence (GBV). This has led to severe food insecurity across north-east Nigeria. Females, in their quest for survival, are often pushed towards negative coping mechanisms such as sex work. Young boys, in their desperation, become easy targets for recruitment by non-state militant groups. The table below captures the causes of the conflict:

Table 2: Main factors of the conflict in North-East Nigeria, by type and field

	Structural / Root	Factors Intermediate/ Proxy	Factors Triggers	Crisis Dynamics
Social	Poor social and economic outcomes (poverty, health, nutrition employment); high inequality; perceived social injustice; lack of social service provision	Declining trust and eroded social cohesion; political manipulation of society and patronage	Social polarization; openness to radicalisation; revenge.	Changing gender and intergenerational relations; sexual and gender-based violence; displacement; inter-communal violent
Political / Governance	Elite political settlement excluding majority; historic marginalization of North-East as a region; poor performance of government institutions; low accountability and legitimacy	Accusations of corruption and impunity; non-State actors fill governance and service void (e.g. community and religious associations); traditional institutions eroded.	Parties take to the street in the absence of effective or trusted channels for re-dress, justice, or political change	Fractured social contract; lack of transparency and poor accountability creates a spiral of violence.
Security	Low levels of human security as a result of poorly performing State security services; porous borders in an insecure wider region.	Supply of unemployed and disaffected youth, proliferation of arms create conditions for recruitment and growth of armed groups and criminal opportunism	Unlawful acts by State and non-State actors; Human rights and humanitarian law violations drive sense of injustice and persecution	Excessive use of force by elements of the security establishment legitimizing rebellion, vigilante groups (Civilian JTF) fill security vacuum with mixed consequences.
Economic	Lack of economic infrastructure, access to markets, and effective policies to support	Lack of jobs and opportunity; large population of unemployed and poorly skilled	Collapse of Northern Nigeria industrial base; recruitment of armed fighters from	Military expenditures thwart development spending; Low human development

	agriculture and industry; high levels and poverty and food insecurity.	youth.	labour force incentivizes violence.	outcomes heighten risk of ongoing or renewed conflict.
Cultural / Ideological	Religion as source of political legitimacy; History of (sometimes violent) religious radicalism challenging the State.	Political manipulation of religion; sharia implementation results in disillusion.	Escalating conflict (widening targets; suicide attacks)	Religious factionalism and competition; rise and internationalization of conflict
Environmental	Climate change and environmental degradation: drought, desertification, contraction of Lake Chad Basin	Lack of demarcated grazing lands, cattle routes and water sources for livestock, agriculture and fisheries	Competition over land and natural resources, especially between agriculturalists and pastoralists.	Lack of effective natural resources and conflict management.

Source: North-East Nigeria Recovery and Peace Building Assessment Report (2016), P34

4.1 Boko Haram Devastation of the North-east and Nigerian Government' Stabilisation Programme and Outcomes

While previous studies have interrogated the motivations of Boko Haram and the role of security agencies in counterinsurgency, explanations of the escalation of Boko Haram attacks on Nigerian security agencies have received limited academic attention and so do the stabilization programme. This section examines the stabilisation programme operations in Nigeria north -east within the context of the bottom-top thesis. It argues that governance approaches enjoy higher community acceptance than top-down approaches. However, it is unclear why this is the case. Our hunch is that it is as a result of community stabilisation of the IOM which was part of our thesis.

In order to correct the impression that donor agencies and other multi-lateral agencies and countries were not foot-dragging on the humanitarian catastrophe in the region, international donors have identified restoring local-level conflict prevention and resolution mechanisms as a central priority. While programs vary in their design, they are based on the basic theory of change that supporting communities to better articulate their concerns and needs to government officials and security agencies—and training the latter to listen to these concerns—will help ensure more effective responses to local-level threats, build popular trust in security forces, and help manage future tensions and shocks.(http://iati.dfid.gov.uk/iati_documents/25184166.pdf).

Even before the conflict erupted, citizen trust in formal security forces (army, police, civil defence) had eroded due to corruption, inefficiency, brutality and weak accountability. An example is the increasing extra-judicial killing of the Boko haram founder. Insufficient coordination and inter-agency rivalries between and among security forces and actors often resulted in delayed and heavy-handed responses to local security threats—a problem not unique to the northeast, but prevalent across Nigeria (Eme, 2018) The insurgency dramatically exacerbated these challenges. The military's inability to protect civilians in the early years of the conflict generated widespread resentment. Communities accused security forces of targeting the population and the air force targeting them with their wrong targets, collaborating with the insurgents, and prolonging the fighting for financial gain. As Boko Haram has been pushed back, relations between citizens and security forces have improved in some localities. Yet fear and mistrust are still pervasive, and civilians often prefer turning to community militia—such as the Civilian Joint Task Force (CJTF)—for protection (Kukah Centre and Conciliation Resources,2017)

At the same time, the conflict has weakened the authority of traditional and religious leaders, who have historically played central dispute resolution roles. Many left their communities during the conflict; others were deliberately targeted by insurgents for refusing to collaborate. Some community elders have also seen their authority challenged by youth militia formed during the conflict. Together, these developments have created a local leadership vacuum at a time when the risk of land and property-related conflict is particularly high (Geraud ,Magrin and Marc-Antoine Perouse de Montclos,2018). Disruptions in grazing routes and decreases in arable land have exacerbated conflicts between farmers and

herders, while protracted displacement has caused friction between internally displaced persons (IDPs), returnees, and host communities.

Specifically, Mercy Corps and consortium partners, Center for Civilians in Conflict (CIVIC), Centre for Humanitarian Dialogue (HD) and Okapi Consulting in a learning event that marked the end of the Northeast Conflict Management and Stabilization (NE-CMS) program, shared insights into the complexities and lessons learned that comes with managing conflict sensitive programming in Northeast Nigeria.

The prolonged crisis in Northeast Nigeria is because of distinct complex root causes, which, if left unaddressed, will continue to undermine long-term peace and stability. The broken social contract amongst the government, traditional leaders, and citizens has often been used as one of the primary drivers of recruitment into and support for non-state armed groups, which continues to be a critical grievance of local communities.

With the aim to improve security and reduce support for violence in Borno state, the program implemented an array of peacebuilding, good governance and civil-military relationship building interventions to support the government's effort to ensure lasting peace in communities hard hit by the insurgency.

The NE-CMS program worked with local communities across Borno State to build their capacity to hold the government accountable for effective service delivery; engage youth as positive change agents; and create safe spaces to manage social and political tensions.

The program started as a pilot in August 2016 and transitioned into a second and third iteration that ended in May 2021. Through conflict assessments and a series of dialogue on the mitigation and prevention of conflict across communities, the NE-CMS program has tackled a range of socio-cultural conflict.

In response, like the local NGOs several donors—including the UK Department for International Development (DFID), the European Union (EU), and the U.S. Department of State—have funded "upstream conflict prevention" programs focused on strengthening dialogue and coordination between communities, local authorities, and security actors. Some programs bring together civilians and security personnel to monitor, report, and discuss local security problems and jointly plan responses, and provide training for community leaders and members in peaceful dispute resolution. Others have created permanent forums and information channels across multiple levels of governance. For example, they combine community-level peace monitors tasked with identifying emerging security threats with platforms that bring together key stakeholders at the community or local government area (LGA) level to address these reports. Many include a specific focus on integrating women and girls into discussions of security challenges and improving reporting on gender-based violence. Some programs, including DFID's Nigeria Stability and Reconciliation Programme (NSRP) and its follow-up, the EU-funded Managing Conflict in North East Nigeria program, also feature state-level forums tasked with tackling challenges that rise beyond the local level. Part of the objective of these programs was to bridge gaps between Nigeria's multiple and often competing security institutions, including the military, the National Police Service, the Nigeria Security and Civil Defence Corps, the Federal Road Safety Corps, and the CJTF.

In order to support these local initiatives, the Federal Government in 2018, created an interventionist agency, the North East Development Commission, NEDC,which in 2022 lunched the Stabilisation Development Masterplan for the region which will gulp the sum of N32 trillion over 10 years period to address the NCDC challenges.

In 2002, when the Jamā'at Ahl as-Sunnah lid-Da'wah wa'l-Jihād, otherwise known as Boko Haram was founded by Mohammed Yusuf, little was known about the terror group. The main goal was to "purify" Islam in Northern Nigeria, believing jihad should be delayed until the group was strong enough to overthrow the Nigerian government.

Yusuf, the leader of the terror group was killed in 2009. After his death, he was succeeded in July 2010 by his former second-in-command, Abubakar Shekau.

Unlike the way the military was able to crush the uprising of the Maitatsine movement led by Muhammadu Marwa in 1985, Boko Haram has been able to thrive despite government onslaught.

The havoc wrecked by the terror group on the region is unprecedented given that the Boko Haram insurgency nodoubt has led to the death of about 350,000 deaths, displaced over 14.8 million people, and left millions needing humanitarian assistance(Akinwale, 2022, https://www.thenewhumanitarian.org/news-feature/2024/04/23/northeast-nigeria-those-who-fled-conflict-are-being-returned).

NEDC was established to address the need to respond to the dire humanitarian needs of the people of the North-east which has been devastated by the insurgency.

The NEDC() Act mandates the Commission to liaise with Federal Ministries, Departments and Agencies, States and Development Partners on the implementation of all measures approved in the Master Plan for the stabilisation and development of the North-East Zone by the Federal Government. It also requires the NEDC to interface with Development Partners (Local or International) and Non-Governmental Organisations to ensure synergy with other Stakeholders in line with the Master Plan'.

A strategic Master plan for the recovery, stabilisation and long -term socioeconomic development of the North-Eastern region of Nigeria, has been unveiled and validated.

The ten-year Master plan is built on eleven pillars which comprises the key sectors needed for the steady return and sustainable development of the region.

Unveiling the Master plan, in Abuja Nigeria, Secretary to the Government of the Federation, SGF, Boss Mustapha said over thirty-one trillion naira is needed to implement the projects.

The SGF said there's need for all Stakeholders in the Public and Private Sectors, Development Partners, especially Donors, to garner resources and invest optimally in the richly endowed, but least-exploited North-East Region.

The 11 Pillars are:

(i) Peaceful Society

(ii) Leadership in Agriculture

(iii) Healthy Citizens

(iv) Educated Populace

(v) Flourishing Trade

(vi) Productive Entrepreneurs

(vii) Purposeful Infrastructure

(viii) Industrialization

(ix) Memorable Experience

(x) Protected Environment

(xi) Connected Region

It runs from 2020 to 2030 in four implementation phases; Recovery & Stabilisation (2020 – 2021), Renewal (2022 – 2023), Expansion (2024 – 2025) and Sustainable Growth (2026 – 2030).

Unlike the Niger Delta Development Commission (NDDC) that has become an ocean of corruption for the people of the region, NEDC was in haste to make a mark and intervene in the suffering of the people and stabilisation of the region. While the commission worked on its master plan, its modest achievements in the last four years have been gratifying. Among the achievements are discussed thematically by Akinwale(2022):

1 Housing
The commission has completed 1,000 housing units in Ngwom, Mafa local government of Borno state. The houses were commissioned by the then Minister of Humanitarian Affairs Disaster Management and Social Development, Sadiya Farouq. The houses have been handed over to the beneficiaries. Also, the commission is constructing another 500

housing units in each of the remaining states to relocate and resettle Internally Displaced Persons (IDPs). This is expected to be continually carried out in order to ease the suffering of all affected families of the region.

2 Information Communication Technology

Aside from the provision of housing units, the commission, in line with its strategic plan to improve access to Information and Communication Technology (ICT), established ICT Resource Centres in each of the six states of the region which are hosted in tertiary institutions in the states.

The Commission has trained over 3,000 youths across the six North East states in ICT. 45 per cent of the beneficiaries are female. The intervention is expected to generate new and sustainable jobs for the youths of all categories cutting across a range of skills. Already, 1,800 youths have been trained in graphic design, 1,718 trained in smart phone repairs across the six states of the region. To ensure the programme gets to the target youth, the commission established 18 ICT Centres in each Senatorial zone.

3 Health

The Commission has distributed hundreds of thousands of food and non-food items in all the North-East states, namely: bags of rice, cartons of spaghetti, gallons of vegetable oil, clothing items for men and women, mosquito nets, pairs of slippers, antiseptic soaps, blankets, mattresses, mats, children's wears, mats, mattresses and many other items.

Furthermore, NEDC has provided advanced health facilities, ventilators, hospital beds, ambulances, consumables, and provision of basic therapeutic capabilities to the Tertiary Health Institutions in the region to curb the spread of Covid-29 virus. Molecular Laboratories in all the North-east States.

In addition to the already provided aid, two Burn Centres were also built in Adamawa and Borno States along with various Medical Outreaches.

4 Humanitarian Intervention

The commission distributed relief materials across the North East states to over 500,000 households. 30,000 persons were reached with returns of food and non-food items in return communities, while over 4,500 displaced Persons benefited from emergency health intervention projects.

5Capacity Building

The commission has trained 500 key stakeholders on Alternative Dispute Resolution; while 150 auto mechanics are currently undergoing training in Vehicular Diagnostic Training. Also, 300 community leaders have been trained on the dangers of improvised explosives and 2,830 beneficiaries trained under NEDC environment protection plan, among others

6 Rapid Response Intervention

The Commission in its short-term developmental plan in the first quarter of 2020 is in the process of implementing over 1000 Rapid Response Intervention (RRI) Projects in Agriculture, Environment, Education, Health, Energy/Power and WASH Sectors across all the 112 LGAs in the six states of the region.

Some of the projects have been completed. While many others are currently in progress with very promising results. In all, over 4000 (RRI) projects have been implemented since 2020.

The commission said in the coming years, there is the hope that more projects will be approved and implemented with the same vigor and goodwill.

Special Development Projects

The commission has also completed a few special projects in the region. The projects are: reconstruction of three bridges along the road from Mararaba Mubi, Adamawa State to Bama in Borno State. Construction of 54km Mutai to Ngalda

sector of the Gujba Ngalda Road in Yobe State; Construction of Mayo Ndaga Road in Taraba State. Reconstruction of police stations and barracks destroyed by insurgents in Garkida, Adamawa State; construction of three bridges on the Jabbi Lamba to Bele Road in Adamawa State;

Rehabilitation of the Maiduguri- Bama road in Borno State; construction of three mega schools in each member state; and construction of Soro Cattle Market in Bauchi State. As soon as the implementation of the masterplan begins, the restoration of the region to its past glory and a better future is just a matter of time.

5 Sharing lessons for stabilizing peace in Northeast Nigeria

5.1 Enhancing governance and peace building in the North-east through community participation

Mercy Corps' mandate for instance was on improving governance, promoting livelihoods for young people and women as a means for reducing insurgency motivations, promoting social cohesion and social protection, youth empowerment, and local conflict management. With collaboration with local partners - Herwa Community Development Initiative, Christian Association of Nigeria (CAN), Jama'atu Nasril Islam (JNI), and Women in New Nigeria (WINN) Mercy Corps supported a series of cultural and religious events across 20 communities. This provided a means of building social cohesion and a platform through which communities could discuss their religious and cultural differences and identify solutions for lasting peace.

The establishment of Youth Support Networks and Women Councils to serve as safe spaces where youth and women can learn new skills, build confidence, and generate unique solutions to community peacebuilding challenges. Mercy Corps provided training and mentorship to these platforms, utilizing peer-to-peer techniques for addressing conflicts, advocating for the needs of youth and women within the broader community, and implementing local initiatives that contribute to youth and women's empowerment, inclusion, and community development.

5.2 Empowerment

Through the establishment and empowerment of Good Governance Committees, community members have been provided with the skills to engage state authorities through dialogues and advocacy, which have produced tangible rehabilitation projects that address local community needs.

5.3 The place of Countering Boko Haram narratives in promoting peace

Centre for Humanitarian Dialogue's work for instance focused on expanding the dissemination of an alternative narrative document to reach key stakeholders in Borno state, with the aim of reducing the vulnerabilities to Boko Haram messages.

Authored by a team of 40 Islamic scholars and clerics in Borno State, it provides a codified response to the key arguments made by violent extremists, which addresses the local socio-cultural contexts that often influence acceptance of extremist messaging. Using the resources developed from this document, the program sensitized communities and facilitated dialogue, to support community action against the support for violence.

During the advent of COVID-19, when face-to-face meetings became a challenge for holding physical sensitizations, Humanitarian Dialogue worked with its community partners - the Borno Peace Champions (BOPCHA) and Women in Dialogue (WID) to open a sensitization page on Facebook (Borno Peace Forum) through which COVID-19 and peace messages were disseminated.

The gains made on alternative narratives indicate that it provides a tool for communities to continuously seek middle grounds and hold difficult conversations towards resolving intra and inter-communal conflicts and deep issues fueling the crisis.

5.4 Radio as a peacebuilding tool in the Lake Chad Basin

Leveraging on the alternative narrative document developed by Humanitarian Dialogue, Okapi Consulting started a radio program to reach a wide audience across the lake chad basin with alternative narrative messages against the support for extremist ideas. Messages were broadcasted in Kanuri, Kanembu and Buduma 6 hours a day on shortwave across the

Northeast and four countries in the Lake Chad Basin (Cameroon, Chad, Niger and Nigeria). One radio station under Okapi's network is able to reach approximately 9-11 million Kanuri-speakers across four countries. The programmes also provide a platform for 2-way communication between the military and civilians.

Amidst direct threats from Boko Haram, Okapi produced and broadcasted 54 alternative narratives programs encouraging more space for debate about different interpretations of Islamic texts; 108 radio programs aimed at strengthening social cohesion were broadcast, and 594 radio programs designed to improve social cohesion were broadcasted.

5.5 Fostering positive civil-military relationships

In response to the program's goal to foster a good relationship between the government, military and civilians, while ensuring their protection, Centre for Civilians in Conflict (CIVIC) provided capacity development training for Nigeria military personnel on protection of civilians (POC) and civilian harm mitigation (CHM). They also established and trained 100% civilians led platforms that are championing advocacy efforts towards POC and CHM. This advocacy has cascaded upwards for the adoption of the National Policy for the Protection of Civilians. They are currently carrying on an engagement with the Civil Society Legislative Advocacy Centre (CISLAC) to support members of the Nigerian National Assembly interested in legislation to further codify Protection of Civilians (POC) in Nigeria.

Despite considerable progress made on the program, the impact of COVID-19 and heightened insecurity has caused so much apprehension in the communities, posing a challenge for sustaining gains made for ensuring lasting peace. However, reflecting on the work done on the program, the following opportunities were presented as recommendations for producing positive results for future security and peacebuilding programming for fragile contexts such as Northeast Nigeria.

5.6 Opportunities for adaptations and future programming: Recommendations

The governments of the North-east should suspend its camp closure policy especially in Borno, while taking measures to better protect those who have been relocated from harm, including by permitting NGOs to provide them with services and by allowing them to move to places they find more suitable. Deeper training, mentorship, and trust building initiatives that could further program goals and sustain program impact are relevant.

Despite multiple difficulties in the region, donor-funded local-level stabilization programs have shown positive impacts in some areas—though they also face a number of program-specific challenges. Conflict prevention and resolution mechanisms have proven effective at the local level, yet their reach is limited. If well-designed and coordinated, such programs have helped address local sources of insecurity, and improved communication flows between citizens, security officials, and local government. Given that the conflict has heightened the risk of intercommunal as well as property and resource disputes, such mechanisms can play an important role. Going forward, it will be essential for donor-funded efforts to better integrate local communities beyond a narrow group of stakeholders and to plan for long-term sustainability rather than creating parallel structures to traditional mechanisms that risk disappearing once funding runs out. Bolster engagement with existing peacebuilding forums, including North East Development Commission (NEDC) and to strengthen dialogue platforms are essential. Again, stakeholders should assess the current state of intercommunal relations and how the conflict has affected inter-communal relations and community perceptions on the preconditions for reconciliation with individuals associated and promote peace building initiatives.

There is need for security sector and governance accountability among all stakeholders in the zone. A longer-term shift toward community-oriented policing will require complementary programming that targets state- and federal-level security reform incentives in the security sector.

Efforts have been made to support both a national DDR framework and local-level reintegration have intensified, they remain stifled by a predominantly militarized approach to the conflict. The U.S. government began pushing for a DDR framework starting in 2015, creatively using appropriation rules in order to work directly with the Nigerian military. Yet U.S. officials struggled to identify committed counterparts, and the process moved slowly. Since then, the government's buy-in non-kinetic approaches to incentivizing the defection and ensuring the reintegration of low-level fighters has increased.

The Nigerian government has launched Operation Safe Corridor, a small-scale defectors' program, and developed a national DDRR Action Plan. Yet donors note that the military maintains tight control over the process: the screening and

vetting of detainees is still not subject to civilian oversight, and many Boko Haram suspects arrested in previous years remain in detention, despite little to no evidence of ties to violent extremist groups. As a result, it is unclear to what extent current efforts truly incentivize defection, while poorly prepared reintegration efforts risk creating further instability and resentment (Aluko O., Isenyo ., Abraham ., Tyopuusu, 2019, June 19).

> There is need for deeper engagement with women and youth thereby strengthening and supporting social inclusion and participatory governance approaches, radio programming and alternative narratives. Regional Radio approach: The Northeast Nigeria crisis is interconnected with Lake Chad Basin crisis. Therefore, interventions need to be regional to address the interconnect issues fueling the support of insurgency. Learning from experience: by letting concerned parties to the conflict speak through radio, the people are given a chance and a voice to speak their truth.

Moreover, while the government has paid lip service to the need for a multidimensional conflict response, it has failed to systematically investigate and prosecute security sector corruption and abuses. Nigeria's international partners should continue to push for greater civilian oversight of the military's screening processes and detention facilities, building on the coordinated pushback against premature relocations of IDPs. The military cite the infiltration of Boko Haram members into the IDP camps (Adibe ,2020, February 20). Federal and state authorities should also send more support and services to larger resettlement sites in towns away from the war zones so that these places can receive IDPs who are required to leave insecure locales. They should lift restrictions that might prohibit these and other IDP movements. State authorities should create more channels for IDPs and humanitarian NGOs to report the problems that relocated individuals are facing so that these can be adequately addressed.

6 Conclusion

In late 2016 and early 2017, military advances against Boko Haram in northeastern Nigeria spurred a greater international focus on local-level stabilization efforts to address root causes of insecurity in the region. Issues the study identified include that the stabilization efforts have emerged: efforts of the stakeholders have strengthened local security mechanisms, restored civilian administration and basic services; and support for the reintegration of former fighters and others associated with nonstate armed groups. All these have improved civil-military relations with the hunch that majority of these stabilization programs were designed with the underlying assumption that the security situation would continue to improve, thereby facilitating the return of displaced populations and local government. For many donors, the overarching objective was to help Nigerian civil and military authorities re-establish a government presence in recaptured areas and begin the programming aimed at preparing the ground for longer-term recovery and development.

The study also observed that irrespective of pressure from donor agencies for the government to fight security sector corruption, it has not yielded any result and as a result a reversal of the gains made. While the Nigerian government has been eager to demonstrate progress in reconstruction, donors point to the longer-term threat of ISWAP gaining a greater foothold in the rural areas around Lake Chad. Local-level programs rely heavily on the theory that they will create "islands of stability" that will eventually forge connections with each other. Yet it is unclear if this assumption holds true in a context of continued insecurity.

Another finding is that the Nigerian case highlights the challenges of implementing effective local-level stabilization efforts while working with and through a host government that lacks political commitment, capacity, and coordination. Particularly in the early years of the crisis, donors struggled to identify effective counterparts for nonmilitary conflict responses. While the situation has improved over time, challenges of coordination persist. Donors particularly point to the duplication of emergency response bodies with overlapping mandates and the severe lack of transparency in Nigerian response operations as a persistent challenge.

While the government under Buhari has emphasized physical reconstruction and socioeconomic recovery programming, which holds the promise of further resource transfers, it appears much less committed to addressing the governance dimensions of the crisis or to ensuring citizen involvement in and oversight of the recovery process.

Again, the internationalization of these challenges is not unique to Nigeria, the regional dimension of the crisis adds additional complexity. Effectively addressing the root causes of insecurity will require a regional approach, particularly in order to ensure the reintegration of low-level Boko Haram members and affiliates, support the return of basic services and trade to the rural areas surrounding Lake Chad, and tackle environmental degradation and resource conflicts. While donors have supported the development of a regional stabilization strategy, organizations on the ground note that these efforts are

still in their infancy, and have so far not been sufficiently felt by local communities. The region lacks an effective political infrastructure, and political commitment to a common approach has so far been relatively weak.

Despite these overarching difficulties, donor-funded local-level stabilization programs have shown positive impacts in some areas—though they also face a number of program-specific challenges as the study observed.

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Assessment of Digital Diplomacy Initiatives for Mitigating Insecurity and Promoting Peace in North East, Nigeria

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Abstract

This study examines the effectiveness of digital diplomacy initiatives in mitigating insecurity and promoting peace in North East Nigeria, a region plagued by the insurgencies of Boko Haram and ISWAP. Digital diplomacy, involving the strategic use of digital platforms to communicate and engage with affected communities, is explored as a tool to counter extremist narratives and foster local peacebuilding. Utilising a qualitative approach, this research analyses interviews with key stakeholders, highlighting the role of digital platforms in facilitating real-time communication, community engagement, and the dissemination of counter-narratives. The findings reveal that while digital diplomacy has improved communication and enhanced community involvement, its impact is limited by challenges such as infrastructure gaps, cybersecurity risks, and low digital literacy. Thus, the study emphasises the need for enhanced digital infrastructure, stronger cybersecurity measures, and capacity-building initiatives to fully leverage digital diplomacy's potential in promoting stability and peace in conflict-affected areas.

Keywords: Digital Diplomacy, Peacebuilding, Insecurity, North East Nigeria, Conflict Resolution, Social Media Diplomacy

1 Introduction

Digital diplomacy involves leveraging digital technologies and social media by both state and non-state actors to engage with domestic and global audiences, aiming to advance policy objectives and foster public engagement [1], [2]. This strategy includes activities such as information sharing, local community engagement, and promoting counter-narratives to extremist ideologies [3], [4]. In regions like Northeast Nigeria, where Boko Haram has created considerable instability [5], digital diplomacy can play a crucial role in strengthening peacebuilding efforts and countering extremist narratives.

The importance of digital diplomacy in resolving conflicts is particularly clear in dealing with Boko Haram and ISWAP. These groups have used social media to disseminate extremist ideologies and attract followers, necessitating a strategic response from governments and civil society [6], [7]. Digital platforms enable stakeholders to spread messages that encourage peace, tolerance, and inclusion, which helps reduce the appeal of extremist ideologies [8]. Furthermore, digital diplomacy allows for real-time communication with conflict-affected communities, deepening the understanding of their needs and fostering trust between authorities and citizens [9].

Furthermore, the interactive nature of digital platforms also aids in mobilizing grassroots movements and including diverse participants in peacebuilding initiatives. This approach can improve the credibility of peace efforts, making them more likely to connect with local populations [10]. For instance, digital campaigns that emphasize the positive role of local communities in preserving peace can counter the negative narratives spread by extremist organizations [11]. Additionally, digital diplomacy can facilitate the coordination of humanitarian aid, ensuring that support reaches those in need even amid conflict [6].

Recent research emphasises the need to incorporate digital strategies into public diplomacy to enhance peace and security. Findings indicate that community-based peace education, particularly among youth, can be scaled effectively through digital platforms [12]. Traditional leaders, crucial in fostering harmony, can use digital channels to promote messages of peace [13], [14]. The influence of social media on shaping public discourse is also notable, as demonstrated by the #EndSARS protests in Nigeria, which showed how digital platforms can engage citizens and influence policy [15], [16]

However, despite these promising developments, a notable gap remains in the understanding of how digital diplomacy can be systematically applied to address the unique challenges of insurgency in regions like North East Nigeria. While much research has focused on the broader applications of digital diplomacy, there is limited evidence on its specific role in countering the narratives of violent extremist groups and in coordinating peacebuilding efforts within this context. This study seeks to fill this gap by assessing the effectiveness of digital diplomacy initiatives in mitigating insecurity and fostering peace in North East Nigeria, providing valuable insights into the opportunities and challenges of leveraging digital tools in conflict resolution.

1.1 Objectives of the Study

1. To evaluate the effectiveness of digital diplomacy initiatives in countering violent extremism and fostering peace in conflict-affected regions of North East Nigeria.

2. To assess the challenges posed by digital infrastructure gaps and cybersecurity threats in the implementation of digital diplomacy initiatives aimed at promoting peace and security in North East Nigeria.

2. Literature Review
2.1 Public Diplomacy

The concept of public diplomacy has evolved significantly, especially during the Cold War, where it served as a national security strategy to counter opposing narratives and promote cultural values [17], [18]. A key component of public diplomacy is cultural diplomacy, which acts as a link between nations by encouraging exchanges of ideas, traditions, and values. This dimension is essential because it allows countries to showcase their cultural heritage and societal norms, fostering greater understanding among international audiences [19]. For example, the United States has used cultural diplomacy through initiatives like the Fulbright Program to encourage educational exchanges and improve its global image [20]. Similarly, modern efforts such as Indonesia's culinary diplomacy demonstrate how nations can use cultural elements to strengthen diplomatic relationships and improve their international standing [21].

Furthermore, public diplomacy extends beyond merely sharing a nation's perspective; it requires engaging and listening to foreign audiences. This reciprocal communication is critical for establishing credibility and trust, which are fundamental to successful public diplomacy [22]. The importance of listening is highlighted by the need to align public diplomacy with policy goals, ensuring that the messages resonate with the values and expectations of the intended audience [23]. This approach focuses on the role of civil society and grassroots movements in shaping perceptions and fostering dialogue, thereby improving the effectiveness of public diplomacy efforts [18], particularly in places battling insecurity.

In the digital era, digital diplomacy has emerged, with social media and online platforms becoming central tools for engagement. In this wise, digital diplomacy enables nations to increasingly use these platforms to reach larger audiences and enable real-time interactions, thereby amplifying the impact of their diplomacy activities [24], [25], including the area of peace building. However, this transition also presents challenges, such as the rapid spread of misinformation and negative narratives, which require a strategic and adaptive response in public diplomacy.

In contemporary times, digital diplomacy has become a crucial tool for nations to project soft power, connect with international audiences, and promote cross-cultural dialogue. By incorporating cultural diplomacy, active listening, and modern communication methods, countries can better manage the complexities of local and global relations and bolster their influence on the world stage.

2.2 Insecurity Issues in North-East Nigeria

The insecurity in North-East Nigeria stems from a complex mix of armed conflict, humanitarian challenges, and socio-economic issues. The region has been greatly affected by the Boko Haram insurgency, resulting in extensive violence, displacement, and a severe humanitarian crisis. Since the conflict's intensification in 2009, it has caused around 350,000 deaths and displaced more than 2 million people, creating a need for humanitarian aid for over 7.7 million individuals [26], [27].

The ongoing violence has significantly interrupted educational access and social services, especially for women and youth. Many young people in North-East Nigeria have suffered intense violence, which has long-lasting psychological impacts, heightening their vulnerability to mental health issues, including suicidal tendencies [28], [29]. The interruption of educational services has also led to a sharp rise in child marriages, with young women in the region being more likely to marry before 18 than those in other areas of Nigeria [30].

Additionally, the insurgency has had a severe economic impact, causing substantial losses for both local and international investors. The region has seen an estimated $9 billion in lost investments due to the persistent violence and instability [31]. This economic decline has exacerbated poverty levels, perpetuating the cycle of insecurity as some individuals resort to illicit activities for survival [32]. While traditional approaches to mitigating the insecurities challenge appear to be insufficient, the adoption of more innovative approaches like digital diplomacy to counter extremism and promote peace is becoming more imperative.

2.3 Peacebuilding

A well-known framework for understanding peacebuilding consists of a three-pronged strategy: peacekeeping, peacemaking, and peacebuilding itself. Peacekeeping aims to halt violence, peacemaking focuses on negotiation and conflict resolution, while peacebuilding seeks to establish a culture of peace through social and economic development [33]. This holistic approach is crucial because it acknowledges that stopping violence alone is inadequate for long-term stability; it requires addressing the underlying socio-economic injustices that drive conflict [34]. For example, in Southeast Asia, ASEAN's community-building strategy highlights the linkages between peace, security, and development, promoting a transformative model that encourages inclusive communities and social justice [35].

Moreover, education is vital in peacebuilding, especially in influencing the attitudes and actions of future generations. Peace education programs have been shown to decrease aggression and instill a culture of peace among young people [36]. Initiatives that involve children and youth in participatory activities, such as theater-based interventions, not only build their sense of agency but also enable them to actively contribute to peacebuilding efforts [37]. This bottom-up approach aligns with the concept of "everyday peace," which values local agency and emphasizes the role of community-driven initiatives in fostering resilience and transforming conflicts [38].

Additionally, the use of arts in peacebuilding has emerged as a significant method for promoting healing and reconciliation. Arts-based peacebuilding projects create opportunities for individuals and communities to express their experiences, facilitate dialogue, and foster understanding [39]. Such approaches can be especially effective in situations where traditional dialogue methods have proven inadequate, as they provide avenues for creative expression and emotional healing [40].

The contribution of women to peacebuilding is also vital, as they often act as pivotal agents of change within their communities. Women's groups frequently bridge ethnic and geographic divides, forming networks that support sustainable peace [41]. Approaches like women-to-women diplomacy underscore the importance of gender-sensitive strategies in peacebuilding, enabling women to challenge narratives of conflict and encourage dialogue. This approach is crucial for developing inclusive peace processes that address the diverse needs and experiences of all community members.

2.4 Theoretical framework

The theory of soft power, introduced by Joseph Nye, is fundamental to understanding how influence can be achieved through attraction rather than coercion. It highlights the importance of culture, political values, and policies in shaping a nation's appeal and influence. As Nye explained in Soft Power: The Means to Success in World Politics (2004), the cultural allure of a nation and the appeal of its political values and policies are integral to its soft power [18]. This concept is applicable to digital diplomacy initiatives in conflict zones like North-East Nigeria, where digital platforms are utilized to promote peaceful narratives and engage local communities. These efforts reflect the principles of soft power, aiming to shape attitudes and behaviors without the use of force [42].

The effectiveness of such soft power strategies largely depends on the willingness of target audiences to engage. In the context of North-East Nigeria, this willingness is influenced by local socio-political dynamics and cultural connections. This resembles past instances, such as Turkey's engagement with American cultural products during the Cold War, illustrating how cultural content can act as a medium for influence [43]. Similarly, the digital diplomacy initiatives examined here aim to use online platforms to counter extremist narratives and advocate for peace, relying on local communities' openness to these messages.

However, the application of soft power faces challenges, including conceptual ambiguity and difficulties in assessing its impact, especially in complex settings like North-East Nigeria. Scholars like Saaida [44] argue that relying exclusively on soft power may not be sufficient without the backing of hard power. In digital diplomacy, the relationship between soft power and economic resources is evident. Limited financial support and infrastructure in North-East Nigeria constrain the effectiveness and outreach of digital diplomacy efforts, supporting claims that economic resources are crucial for sustaining cultural and diplomatic activities [45].

The evolving dynamics of soft power are also apparent in the emergence of non-Western players like China, which uses its cultural and political narratives to expand global influence, as evidenced by the Belt and Road Initiative [46], [47]. This development underscores the flexibility of soft power, suggesting that even nations in conflict zones can leverage digital tools strategically to shape public perception and promote peace. Through the application of soft power principles, digital diplomacy in North-East Nigeria aims to achieve stability using non-coercive methods, aligning with the broader goals of this study.

3. Methodology

For this study, a qualitative research approach will be employed, utilising semi-structured interviews with key informants as the primary data collection method. This methodology is selected to provide an in-depth understanding of the perceptions, experiences, and insights of those directly involved in or affected by digital diplomacy initiatives aimed at mitigating insecurity and promoting peace in North East Nigeria.

4. Findings

This section presents a thematic analysis of the study's two main objectives, based on insights from key informant interviews. The first objective evaluates the effectiveness of digital diplomacy initiatives in countering violent extremism and promoting peace while the second objective assesses the challenges posed by infrastructure gaps and cybersecurity threats. The section also profiles the key informants.

4.1 Informant Profile

The four key informants for this study were selected from different relevant institutions and organisations (See Table 1). The first informant (Informant 1) is the Programme Manager, Transcultural Psychosocial Organisation (TPO). He is an expert in community support, reintegration of ex-combatants, and educational initiatives. Informant 2 is the Programmes Manager, Street Child of Nigeria, and an expert in humanitarian and development interventions. He engages in digital diplomacy through existing platforms such as the Reintegration Technical Working Group and Protection Sector. Informant 3 is an expert in humanitarian coordination and peace-building from the United Nations Office for the Coordination of Humanitarian Affairs (OCHA). He coordinates humanitarian responses across Adamawa, Borno, and Yobe states, using digital tools to enhance communication between local communities, security agencies, and humanitarian actors. Lastly, the fourth informant (Informant 4) is a Senior Special Assistant on Media to the Governor of Adamawa State, provides insights into the use of digital diplomacy for mitigating insecurity and fostering peace in North East Nigeria, particularly in Adamawa State.

Table 1: Informant Profile

Informant Name	Role/Organisation	Area of Expertise
Informant 1	Programme Manager, Transcultural Psychosocial Organisation (TPO)	Community Support, Reintegration of Ex-Combatants, Education
Informant 2	Programmes Manager, Street Child of Nigeria	Humanitarian and Development Interventions
Informant 3	UN Office for the Coordination of Humanitarian Affairs (OCHA)	Humanitarian Coordination, Peace-building
Informant 4	Senior Special Assistant on New Media to Governor of Adamawa State	Media, Security Communication, Peace-building

4.2 Objective 1: Evaluating the Effectiveness of Digital Diplomacy Initiatives in Countering Violent Extremism and Fostering Peace in North East Nigeria

This section provides a thematic analysis of the effectiveness of digital diplomacy initiatives in countering violent extremism and fostering peace in conflict-affected regions of North East Nigeria. Drawing insights from key informants, the analysis identifies key themes and sub-themes that demonstrate the ways in which digital diplomacy tools have been implemented, their impact, and the challenges faced.

Theme 1: Real-Time Communication and Crisis Management

Digital diplomacy initiatives have significantly enhanced real-time communication, allowing for swift responses to security threats. Platforms like WhatsApp enable immediate sharing of information, facilitating quicker interventions and coordination between community leaders and security agencies. In line with this, immediate response to security threats and coordination between local and international actors emerged as sub-themes.

Sub-Theme 1.1: Immediate Response to Security Threats

Digital diplomacy initiatives in North East Nigeria have significantly improved real-time communication, enabling faster and more coordinated responses to security threats. Informants consistently emphasised the role of WhatsApp groups and other social media platforms in relaying critical information during crises. For instance, Informant 4 highlighted the importance of real-time communication through WhatsApp, stating, "*We coordinated a rapid response using WhatsApp groups during a violent outbreak in Gombi. Community leaders shared information quickly, and security forces were able to intervene faster than with traditional methods.*" This shows that social media, particularly WhatsApp, allows for quick dissemination of information, facilitating timely interventions and potentially saving lives.

Similarly, Informant 1 elaborated on the use of WhatsApp for real-time coordination across communities and security agencies, noting, "*Whenever there is a communal clash or security threat, the WhatsApp group allows stakeholders, including security forces, to share information instantly and act before the situation escalates.*" This underscores how digital diplomacy has enabled proactive measures, improving the overall capacity to address security risks.

Sub-Theme 1.2: Coordination Between Local and International Actors

Another critical element of real-time communication is the improved coordination between local, national, and international peace-building actors. Informant 3 discussed how digital tools like Teams, Zoom, and WhatsApp have created platforms for strategic collaboration among diverse stakeholders. He explained, "*Digital platforms are essential for bringing together local NGOs, international organizations, and UN agencies to coordinate responses, especially in conflict mediation and peace-building.*" This indicates that digital diplomacy not only facilitates communication at the local level but also strengthens ties between international and local actors, enhancing the overall peace-building framework.

Theme 2: Reduction of Misinformation and Extremist Propaganda

Moreover, digital platforms have been instrumental in reducing the spread of misinformation and extremist propaganda by providing timely and accurate information. However, the challenge of countering propaganda remains, as extremists also use these platforms to incite panic. The following sub-themes buttressed this theme: combating *misinformation* and *challenges with extremist propaganda*.

Sub-Theme 2.1: Combating Misinformation

One of the key successes of digital diplomacy has been its ability to reduce misinformation and extremist propaganda, which are frequently used by violent groups to incite panic and mistrust. Several informants noted the importance of providing accurate and timely information to counter these false narratives. In this wise, Informant 4 pointed out, "*During security incidents, we share real-time updates on social media to prevent the* spread *of panic. Our posts ensure that people receive accurate information rather than relying on rumors or extremist propaganda*." This highlights how digital diplomacy plays a critical role in maintaining public trust by delivering timely and factual updates.

Sub-Theme 2.2: Challenges with Extremist Propaganda

However, the challenge of misinformation persists, as extremist groups often use the same platforms to spread propaganda and false information. Informant 1 mentioned, "*We've seen instances where extremist groups send voice messages claiming that Boko Haram is about to attack a community, which causes panic. We have to act quickly to counter these messages with the truth.*" This demonstrates the dual-edged nature of digital platforms, which can be exploited by both peace actors and extremist groups.

Generally, the efforts to debunk false narratives have proven effective to some extent, but the constant vigilance required to monitor and counter misinformation remains a significant challenge, particularly in regions where digital literacy is low and trust in digital information can be fragile.

Theme 3: Community Engagement and Mobilization

Digital diplomacy has also empowered communities by enabling them to engage directly in security measures and peace-building processes. Platforms such as WhatsApp and radio programs allow communities to provide feedback, report

incidents, and participate in security discussions. This is expanded in these sub-themes: *empowering communities through digital platforms* and *educational and awareness campaigns.*

Sub-Theme 3.1: Empowering Communities Through Digital Platforms
Digital diplomacy initiatives have been instrumental in engaging local communities, giving them a voice in the security and peacebuilding process. Several informants noted that platforms like WhatsApp, radio programs, and podcasts have enabled communities to not only receive security updates but also provide feedback and participate in decision-making processes. Informant 4 noted, "*Through social media platforms, we've been able to engage local communities in discussions on security measures. Citizens can report incidents, offer feedback, and even suggest solutions during online town halls.*" This suggests that digital diplomacy has not only improved top-down communication but has also fostered bottom-up community involvement, ensuring that peace-building efforts are more inclusive.

Sub-Theme 3.2: Educational and Awareness Campaigns
Another dimension of community engagement is the use of digital literacy platforms and radio programs to educate conflict-affected populations. Informant 2 shared that digital platforms have been used to raise awareness about explosive ordinances and provide educational content to children displaced by conflict. He explained, "*We've been using radio programs and podcasts to teach children in affected communities, and we also provide explosive ordinance risk education through pre-recorded messages.*" This demonstrates how digital tools can be used to address educational and security challenges simultaneously, helping communities better navigate their environment and stay safe from potential threats.

Theme 4: Support for Reintegration and Peace-building

Digital diplomacy has played a critical role in promoting the reintegration of ex-combatants, using radio and social media to encourage surrenders and rehabilitation. It has also facilitated remote coordination of peace-building efforts, especially during periods where in-person meetings were not feasible. Under this theme, we have these sub-themes: *encouraging surrender* and *reintegration peace promotion through collaboration.*

Sub-Theme 4.1: Encouraging Surrender and Reintegration
One of the most notable impacts of digital diplomacy has been its role in encouraging the surrender and reintegration of ex-combatants. For instance, Informant 2 highlighted a significant success story in which digital messaging was used to reach non-state armed groups. He shared, "*Through radio programs and social media, we disseminated messages encouraging non-state armed groups to surrender. In 2021, over 60,000 members of armed groups surrendered after hearing these messages.*" This underscores the power of digital diplomacy in not only delivering security updates but also promoting conflict resolution and rehabilitation.

Sub-Theme 4.2: Peace Promotion Through Collaboration
Digital diplomacy has also supported peace promotion by facilitating collaboration among peace-building actors. Informant 3 noted that during the COVID-19 pandemic, when physical meetings were not possible, remote programming allowed peace-building activities to continue. He stated, "*Even when we couldn't meet in person, digital platforms enabled us to coordinate peace-building activities remotely, ensuring that efforts to resolve conflicts didn't halt.*" This indicates that digital tools have provided continuity in peace-building efforts, especially during challenging circumstances.

Theme 5: Strengthening Coordination among Stakeholders

Furthermore, digital platforms have improved coordination among various stakeholders, including local government officials, NGOs, and international actors, ensuring timely and collaborative responses to security threats. These tools have also integrated international expertise into local peace-building initiatives. This theme is further explored through these sub-themes: *cross-sector coordination* and *integration with international peace-building efforts.*

Sub-Theme 5.1: Cross-Sector Coordination

Digital diplomacy has proven effective in enhancing coordination among various stakeholders, including local government officials, NGOs, and international organisations. For instance, Informant 1 discussed how WhatsApp groups have been established at the local government level to facilitate constant communication between civil society, security forces, and government agencies. He explained, "*We created WhatsApp groups with local government officials and security personnel so that when a security issue arises, we can respond immediately by coordinating through the group.*" This reflects the efficiency of digital platforms in fostering collaboration and ensuring that all actors are on the same page when addressing security threats.

Sub-Theme 5.2: Integration with International Peace-building Efforts

In addition, Informant 3 added that international organisations have also leveraged digital platforms to provide technical expertise and strategic guidance. He shared, "*We've used Teams and Zoom to coordinate with international bodies like the UN, ensuring that local peace-building efforts align with global best practices.*" This highlights the ability of digital diplomacy to bridge local and international peace efforts, ensuring that initiatives are informed by global standards.

Thus, the thematic analysis reveals that digital diplomacy initiatives in North-East Nigeria have made notable contributions to countering violent extremism and fostering peace. Through real-time communication, reducing misinformation, engaging communities, supporting reintegration, and enhancing coordination, these initiatives have demonstrated their effectiveness in mitigating insecurity. However, the constant challenges of combating misinformation, limited digital infrastructure, and varying levels of digital literacy indicate that there is room for improvement in fully realising the potential of digital diplomacy in the region.

4.3 Objective 2: Assessing the Challenges Posed by Digital Infrastructure Gaps and Cybersecurity Threats in the Implementation of Digital Diplomacy Initiatives Aimed at Promoting Peace and Security in North East Nigeria

This section focuses on analysing the challenges faced in implementing digital diplomacy initiatives due to infrastructure limitations and cybersecurity risks. The analysis reveals themes and sub-themes from the informants' insights, reflecting the barriers that hinder the effectiveness of digital tools in fostering peace and security in North East Nigeria.

Theme 1: Digital Infrastructure Gaps

A major challenge in implementing digital diplomacy is the *unreliable internet access* in rural areas, which severely limits the reach of these initiatives. This theme also includes the problem of *intermittent power supply*, which disrupts communication and weakens the effectiveness of digital tools. Additionally, *geographical and security* barriers prevent the installation of necessary infrastructure, further compounding these challenges. The lack of reliable infrastructure results in communities being digitally excluded from peacebuilding efforts.

Sub-theme 1.1: Unreliable Internet Access
One of the most significant challenges highlighted by all informants is the issue of unreliable internet access, particularly in rural and conflict-affected regions. This infrastructure gap severely limits the reach and effectiveness of digital diplomacy initiatives. For instance, Informant 2 stated: "*Limited internet access in rural areas drastically reduces the effectiveness of our digital diplomacy efforts. Many of the communities most affected by conflict have little to no internet connectivity.*" This demonstrates how digital exclusion in remote areas poses a barrier to peacebuilding efforts, as the communities most in need of support are often the hardest to reach through digital platforms.

Sub-theme 1.2: Intermittent Power Supply
In addition to internet access, the lack of a reliable power supply is another major challenge. Many regions experience frequent power outages, making it difficult to maintain continuous communication through digital platforms. For instance, Informant 3 discussed the impact of this issue: "*Power outages are a constant problem in rural areas, and without electricity, it's impossible to keep communication lines open, which weakens the effectiveness of our initiatives.*" This sub-theme highlights how the lack of stable electricity further compounds the challenges of digital diplomacy, particularly in areas where other infrastructure is already weak.

Sub-theme 1.3: Geographical and Security Barriers
Informants also pointed out that geographical remoteness and security issues make it difficult to improve digital infrastructure in certain regions. Many areas are inaccessible due to ongoing conflict or challenging terrain, which prevents the installation of necessary infrastructure like cell towers or internet cables. As Informant 4 noted: "*Some areas are simply inaccessible due to the security situation or difficult terrain. Without access to these regions, it's almost impossible to improve internet and digital infrastructure.*" This underscores how security and geographical challenges exacerbate the infrastructure gaps, limiting the ability of digital diplomacy to function effectively in certain regions.

Theme 2: Cybersecurity Threats

Digital diplomacy platforms are vulnerable to exploitation by extremist groups, who often use the same platforms to spread misinformation *and propaganda*. The *low level of cybersecurity awareness* among local communities and organisations exacerbates this problem, making them more susceptible to cyberattacks. Additionally, there are *insufficient cybersecurity measures* at the governmental and organisational levels, leaving peace-building operations exposed to various digital threats.

Sub-theme 2.1: Vulnerability to Extremist Exploitation

A recurring issue across the interviews is the vulnerability of digital platforms to exploitation by extremist groups. Several informants described how extremists use the same platforms intended for peace-building to spread misinformation, propaganda, or even coordinate attacks.

Informant 4 highlighted this challenge: "E*xtremist groups often exploit the same social media platforms we use for peacebuilding, spreading misinformation and creating panic within communities*." This assertion illustrates how cybersecurity threats are not only technical but also social, as extremist groups leverage digital tools to undermine peace efforts.

Sub-theme 2.2: Lack of Cybersecurity Awareness

Another challenge is the low level of cybersecurity awareness among local communities and stakeholders. Many individuals and organisations are unaware of the risks associated with using digital platforms, making them vulnerable to cyberattacks and data breaches. For instance, Informant 3 pointed out: "*Many people in the communities are unaware of the cybersecurity risks they face when using digital tools, which makes them vulnerable to hacking, phishing, and other forms of cyberattacks.*" This sub-theme highlights the need for greater awareness and training on cybersecurity to protect both peace-building actors and local communities from digital threats.

Sub-theme 2.3: Governmental and Organisational Gaps in Cybersecurity Measures

In addition to a lack of awareness at the community level, several informants discussed the insufficient cybersecurity measures in place at the governmental and organisational levels. Many organisations lack the resources or expertise to implement comprehensive cybersecurity protocols, leaving their operations vulnerable to attacks. As Informant 2 described: "*At the organisational level, there's still a lack of comprehensive cybersecurity measures in place. Without proper investment in cybersecurity, we're leaving ourselves exposed to serious risks*." This underscores the urgent need for stronger cybersecurity policies and resources to protect digital diplomacy initiatives from external threats.

Theme 3: Limitations in Funding and Resource Allocation

The lack of adequate funding for *infrastructure development* is a significant barrier to improving digital access in conflict-affected areas. Without sufficient resources, efforts to expand internet access or ensure consistent power supply are hindered. Moreover, there is a *lack of investment in cybersecurity*, with many organisations unable to allocate the necessary funds to protect their digital platforms from attacks.

Sub-theme 3.1: Inadequate Funding for Infrastructure Development

A major challenge in addressing digital infrastructure gaps is the lack of adequate funding to improve internet access, power supply, and other critical infrastructure in rural areas. Several informants discussed how resource constraints limit the ability of both governmental and non-governmental organisations to make necessary improvements. For instance, Informant 2 explained: "*The funding simply isn't there to build the kind of infrastructure we need in remote areas. Without more resources, it's difficult to expand internet access or ensure consistent power supply*." This highlights the financial constraints that prevent the expansion of digital diplomacy to the regions where it is most needed.

Sub-theme 3.2: Lack of Investment in Cybersecurity

In addition to infrastructure, there is a significant lack of investment in cybersecurity, both in terms of personnel and technology. Several informants mentioned that budget limitations make it difficult to hire cybersecurity experts or purchase the tools needed to protect digital platforms. Accordingly, Informant 3 noted: "*Cybersecurity is often seen as an afterthought in our budgeting process, and we simply don't have the resources to invest in the kind of protections we need.*" This sub-theme emphasises the resource gaps that leave organisations vulnerable to cyber threats and limit the effectiveness of digital diplomacy initiatives.

Theme 4: Alternative Strategies to Overcome Infrastructure and Cybersecurity Challenges

To address these infrastructure and cybersecurity challenges, *low-tech solutions* such as radio broadcasts and SMS alerts have been adopted as alternatives to digital platforms. Stronger *collaborations with international organisations* have also been key in providing technical expertise and resources. Furthermore, *capacity-building programs* focused on cybersecurity are necessary to equip local communities and organisations with the knowledge and skills to defend against cyber threats.

Sub-theme 4.1: Use of Low-Tech Solutions

To overcome infrastructure limitations, some informants discussed the use of low-tech solutions like radio broadcasts, SMS alerts, and pre-recorded messages. These alternatives help maintain communication with communities even when digital tools are not viable due to poor internet access or power outages. Informant 3 explained: "*In areas where internet access is limited, we rely on radio and SMS to keep communities informed. It's not ideal, but it's effective in reaching* people *who wouldn't otherwise be connected*." This sub-theme highlights the importance of adapting to local realities by using alternative communication methods that can bypass digital infrastructure challenges.

Sub-theme 4.2: Collaborations with International Organisations
Several informants mentioned the need for stronger collaborations with international organisations to address both infrastructure and cybersecurity challenges. International organisations can provide technical expertise, funding, and resources that are lacking at the local level. Informant 4 stated: "*Collaborating with international organisations like UNICEF and the UN has been crucial in overcoming some of the infrastructure and security challenges we face.*" This illustrates the importance of international partnerships in ensuring that digital diplomacy initiatives are adequately funded and protected against cyber threats.

Sub-theme 4.3: Capacity Building for Cybersecurity
In response to cybersecurity threats, several informants stressed the need for capacity-building programs that teach local communities, NGOs, and government agencies how to protect themselves against cyberattacks. These programs would focus on improving awareness, as well as developing the technical skills needed to secure digital platforms. Informant 3 highlighted: "*We need to train both our teams and the communities on basic cybersecurity measures. Many of the cyberattacks we've experienced could have been prevented with proper awareness and training*." This emphasises the need for ongoing education and capacity building to ensure that all stakeholders can engage with digital diplomacy safely and securely.

By and large, the analysis of the second objective reveals that infrastructure gaps and cybersecurity threats present significant challenges to the successful implementation of digital diplomacy initiatives in North East Nigeria. Key issues include unreliable internet access, frequent power outages, and a lack of cybersecurity awareness and resources. However, alternative strategies such as low-tech communication solutions, international collaborations, and capacity-building programs offer promising ways to mitigate these challenges.

5. Discussion
The findings indicate that digital diplomacy initiatives significantly enhance real-time communication and crisis management in conflict zones like North-East Nigeria, aligning with the principles of soft power, which seek to influence behavior through attraction and engagement [18]. Real-time communication through platforms like WhatsApp has been crucial for rapid responses to security threats, allowing for immediate coordination between local leaders and security forces. This supports the idea that digital tools can foster community engagement and mobilization in peacebuilding processes [9,10]. Similar to the case of Turkey's reception of American cultural products during the Cold War, where cultural content served as a medium for influence [43], digital diplomacy in North-East Nigeria relies on the readiness of local communities to engage with these platforms.

However, the dual nature of these platforms is evident, as they can also be exploited by extremist groups to spread misinformation and incite panic [42]. This underscores a challenge frequently highlighted in the literature, where the adaptability of digital diplomacy to both positive and negative uses complicates its application in conflict-prone regions [8,44]. The challenge of misinformation remains persistent, as indicated by the experiences of key informants, and aligns with existing research on the need for constant vigilance in digital communication spaces [7].

The findings highlight significant digital infrastructure gaps that hinder the reach of digital diplomacy efforts. Issues such as unreliable internet access and intermittent power supply limit the potential of digital diplomacy to fully engage communities in remote areas [26]. These challenges resonate with previous studies on the importance of economic resources and infrastructure in sustaining soft power and digital initiatives [45]. Informants emphasized that the lack of infrastructure results in digital exclusion, making it difficult for conflict-affected communities to access the peacebuilding support they need.

Cybersecurity threats also pose a substantial challenge, with extremist groups using digital platforms for their purposes, highlighting the dual-edged nature of these tools [6,42]. The findings suggest that inadequate investment in cybersecurity measures at both governmental and organizational levels leaves digital diplomacy efforts exposed to potential risks. This aligns with observations that without adequate support from hard power elements, such as security measures and economic investment, soft power strategies may struggle to achieve their intended outcomes [44].

Despite these challenges, digital diplomacy has enabled community involvement through initiatives like online town halls and radio programs, which empower local voices in security discussions [12,39]. This bottom-up approach is consistent with the concept of "everyday peace," emphasizing the importance of local agency in conflict resolution [37].

The adaptability of digital diplomacy is further demonstrated by the use of low-tech solutions, such as radio broadcasts and SMS alerts, which have been adopted to bridge the digital divide [31]. These methods provide a practical means of maintaining communication with remote communities, even when digital infrastructure is lacking.

Moreover, the collaboration with international organizations, as highlighted in the findings, provides essential support for overcoming infrastructure and security challenges [46]. This reflects the evolving nature of soft power in a globalized world, where partnerships and international cooperation play a crucial role in enhancing the impact of digital diplomacy initiatives [23,35]. Capacity-building programs focused on cybersecurity awareness also emerged as a critical need, suggesting that equipping local communities with the skills to protect themselves from digital threats is necessary for the sustainable success of digital diplomacy [45].

6. Conclusion

In conclusion, digital diplomacy has shown promise in countering violent extremism and promoting peace in North East Nigeria by facilitating real-time communication, engaging communities, and combating misinformation. However, challenges such as infrastructure gaps, cybersecurity risks, and low digital literacy limit its full potential, particularly in rural areas. Addressing these barriers is crucial for long-term success. The findings imply that policymakers and peace-builders must prioritize investment in digital infrastructure, especially in underserved regions. Additionally, cybersecurity awareness and digital literacy need improvement to mitigate the risks of misinformation and cyberattacks. Integrating digital diplomacy with traditional peacebuilding efforts will create a more comprehensive approach to conflict resolution. Moving forward, it is recommended that governments and international partners focus on expanding digital infrastructure and strengthening cybersecurity measures. Capacity-building programs should enhance digital literacy and cybersecurity skills among local communities. Moreover, fostering international collaborations will provide the necessary support to ensure the success of digital diplomacy initiatives.

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Voter authentication Framework using Blockchain, Lightweight ring-neighbor-based user authentication and group-key agreement

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Abstract

Global mistrust in election systems, caused by issues like vote rigging and hacking of electronic voting machines (EVMs), threatens democracy. This paper presents a blockchain-based e-voting framework designed to enhance voter authentication and secure voting transactions while addressing the computational challenges of traditional blockchain systems. The proposed system employs group-based voter authentication using a modified ring neighbour algorithm, allowing for decentralized voting, tamper-proof records, and the integrity of vote counts. Key cryptographic elements such as SHA-256 hashing, Merkle trees, and random integer pairwise verification are integrated to secure the election process. A centralized Trusted Authority (TA) handles voter registration and block creation, preventing double voting and impersonation. The blockchain's immutability guarantees that any tampering attempts are computationally infeasible, ensuring secure and transparent election outcomes. This framework addresses the vulnerabilities of current electoral systems, combining cryptographic security, decentralized validation, and efficient voter authentication to ensure a reliable and secure e-voting process.

Keywords: Agreement, Authentication, Blockchain, Electronic voting, lightweight, validation

1. Introduction

The widespread mistrust that large segments of society around the world have for election systems poses a serious threat to democracy. Even the most developed democracies in the world, including the Republic of India, Japan, and the United States, still have imperfect legal systems. Booth capturing, election manipulation, vote rigging, and hacking of the electronic voting machine (EVM) are the primary problems with the current electoral system [1].

Electronic voting, or e-voting, has been around since the 1970s in a variety of configurations. Although securing the process has proven difficult, it offers fundamental advantages over paper-based systems, such as increased efficiency and decreased errors [2]. With the help of blockchain technology, networks can now store and distribute information without requiring external certification authorities or participant knowledge of one another [3]. Thus, blockchain has been used more and more to stop unauthorized transactions in a range of industries thanks to its strong cryptographic foundations. E-voting provides anonymity, or the capacity to vote in secret. The advantages of blockchain to the overall process of voting remain unmatched but due to the drawback of being computationally expensive, there is a reluctance to its application. This paper therefore developed a new blockchain framework that incorporates an agreement module among voters within a block of the blockchain to facilitate voter authentication and transaction validity

2. Literature Review

Beyond its use in cryptocurrencies, blockchain technology is gaining greater traction and finding applications in the Internet of Things (IoT) space [4] . [3]demonstrated how blockchain technology can be used to enhance the more widely used password-based authentication technology, which includes PKI-based authentication technology, smart card authentication technology, technology based on biological characteristics, and technology based on biological characteristics. Modern blockchain platforms have been developed to help overcome limitations and offer valuable value for additional modern business uses and applications. As of 2024, the top three blockchain frameworks for these use cases are R3 Corda, Hyperledger, and Ethereum. The global Corda Network is defined by the set of guidelines, network specifications, and associated governance procedures that comprise the Corda platform, which includes the open-source Corda software project [5].

[2] created a system to facilitate a real-world voting application that supports ledger synchronization, e-voting management, security, and access control, the blockchain e-voting system makes use of cryptographic properties.

[6], based on their system advocated that an election system should forbid the linking of votes to specific voters, permit safe authentication through the use of identity verification services, and ensure transparency by assuring each voter that their vote was counted accurately and without compromising their privacy. It should also make it illegal for any third party to influence a vote, prohibit any one party from controlling the tabulation of votes or the declaration of the election results, and only allow eligible voters to cast ballots. [7] demonstrated the significance of participants' ownership in the

blockchain for the integrity of transactions. They proposed integrating an intermediary server with the main smart contract to solve the voter anonymity issue and create a semi-decentralized system.

[8] conducted a survey to learn about the various blockchain system types that can be used in various contexts. According to their analysis, most blockchain applications used in voting scenarios are permission and primarily use the Proof of Stake consensus (or, in certain situations, the Proof of Authority consensus). Different blockchains were used in different scenarios, and in some cases, each person was assigned their own blockchain. This is due to the computational expenses of a typical blockchain necessitating the need for a lightweight version that still has the ability to facilitate all the properties of a properly run election

[9] suggested a protocol with lower computational and communication costs for group key agreement security, privacy protection, and limited computing power for the Internet of Drones (IoD). Drones that collect sensitive private data are highly susceptible to physical interception and data tampering, particularly when multiple drones are deployed simultaneously for collaborative purposes. They proposed that group communication requirements cannot be met by lightweight computations, conventional schemes, or the limited storage of IoD devices.
Three steps made up the proposed scheme: user registration, group member authentication, and group key agreement. Every user must register with TA in order to use the application. User management falls under the purview of TA, who is also in charge of adding new users and deleting those who are not registered. After a user completes the registration process, TA gives them a special secret token. Their approach builds group keys using binary asymmetric polynomials and uses addition as the primary mathematical operation by following these steps:

> *Step 1:* Every group member chooses an integer at random and announces it to the group.
> *Step 2:* Using their broadcasted values, members compute a shared pairwise key with each other in the group. A function applied to shares of the members' tokens is used to derive this key.
> *Step 3:* Using a cryptographic hash function that combines the pairwise key and the random value of the other member, the member determines an authentication value to confirm identity. The other member receives this value as an authentication response.
> *Step 4:* Using the pairwise key, the receiving member compares the received value to a recomputed value. A member is considered legitimate if their values align; if not, they are considered fraudulent. Until every group member has received their authentication, this procedure is repeated. The procedures guarantee reciprocal member authentication by using cryptographic techniques.

Bivariate polynomial-based methods not only offered information-theoretic security and authentication but also incurred lower computational costs when compared to public-key and lattice-based operations, which have high computational costs.

It was argued that security and scalability are two of blockchain's main problems. Concerning scalability [4] and [10] showed that rational miners would prefer to side with network attackers, and that the colluding group will expand until it consists of a majority, creating a new issue with selfish mining.

Two strategies have been put forth to address the problem of data storage in a blockchain environment: divide the traditional block into two parts, a "microblock" for transaction storing and a "key block" for leader elections; remove outdated transaction records and store them in a new database transaction tree to create a lightweight blockchain version; and prohibit the use of lightweight clients to perform costly computations in place of continuously creating new blocks [11] and [12].

3. Methodology

This paper propses a computationally inexpensive blockchain approach to authenticate the validity of voters in an electronic voting environment by using a group key and lightweight ring neighbour algorithm adopted from [9] and finetuned for this work. This approach affords the legitimacy of vote counts, election outcomes, and the ability to vote from anywhere. The process is described below

i.   The voting application serves as the Trusted Authority (TA) and acts as the custodian for creating blocks, grouping, registration and deregistration of voters in the framework and has a user interface for interaction with the voters. They can access the application using a mobile device or computer over the internet. Voters have to register with the TA to be assigned to a group.

ii. Voter registration details must be made up of at least two unique identification code like the social security number or national identification number and a phone number to eliminate the possibility of double registration by voters. These details must be validated by the TA which allows for account creation. voters can then vote for the candidate of their choice

iii. The TA generates the genesis block and subsequent blocks of the blockchain. Usually, each block has a (i) BlockID to uniquely identify the block (ii) transactions (iii) Merkle root which identifies all the transactions within a given block (there can be more than one transaction within a block), (iv)hash value generated, that is cryptographic hash generated (v)previous hash that is, the hash value from the previous block. Every single block stores a reference to the previous block (vi)nonce which means the number only used once often used within blockchain mining to get the right hashing difficulty value and (vii) Timestamp which is the time a new block is added to the blockchain [13]. The genesis block contains no data asides for the BlockID and a randomly generated nonce which the SHA-256 algorithm uses to create the hash for the block. In this framework, it is only the genesis block that makes use of the nonce property.

iv. Voters are split into n number of groups where members of each group must be equal to 4 but not greater than 100. In the event of the remaining voters being less than 4, a module for direct voting caters for this by the TA and anomalies due to the minuscule number. A token made up of the eight last characters of the previous hash is broadcasted to members of a group to authenticate their identity. After identity authentication, a 4-bit Merkle root value is randomly generated and assigned to the group transaction. Each member can only have one transaction in the entirety of the blockchain.

v. Each member is then requested to generate a random integer that will be broadcast to the closest member of the group based on the assigned voter ID given upon completion of registration. Each voter derives the hash function based on the concatenation of the Merkle root and generated random number to authenticate the inputted hash function value of the paired voter to again authenticate the voter and validate the voting transaction. This guarantees that voters within a block are paired and validate each other's authenticity. Failure to complete this task causes a pair to be deregistered and added to another block upon re-registering on the application

vi. The BlockID, merkle root, and timestamp are then concatenated and hashed to form the hash of the current block which will be linked to the next block. Figure 1 shows a diagrammatic representation of the framework
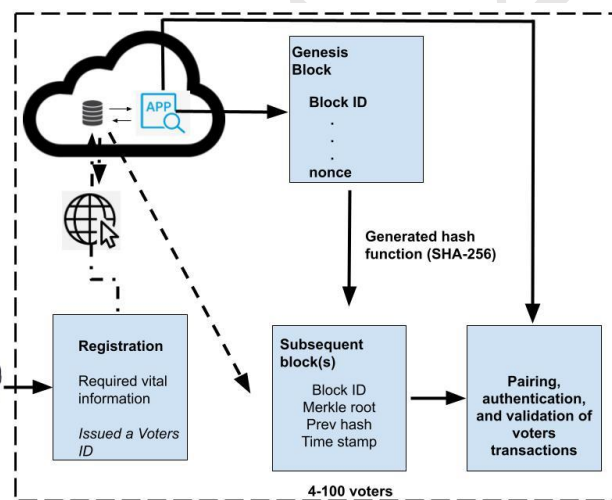

Fig 8. Blockchain-Based Voting System: Registration, Authentication, and Block Creation Workflow

4. Analysis:

a. Cryptographic Hash Functions (SHA-256) Function: A cryptographic hash function, such as SHA-256, takes an input and produces a fixed-size string of bytes. The output, called a hash, is typically represented as a hexadecimal number.

$$H(x) = SHA - 256(x) \quad (1)$$

Here, $H(x)$ is the hash value of the input xxx. The key property is that even a tiny change in x produces a significantly different $H(x)$, known as the "avalanche effect." Each block in the blockchain includes a hash of the previous block, H_{prev}, ensuring that altering any block would necessitate recalculating the hash for that block and all subsequent blocks:

$$H_{current} = SHA - 256(BlockID||Merkle\ root||\ Timestamp||H_{prev})(2)$$

This chaining mechanism makes the blockchain tamper-proof.

b. Merkle Trees: A Merkle tree is a binary tree where each leaf node represents the hash of a block of data, and each non-leaf node is the hash of its children. The root of the tree, known as the Merkle root, represents the entire dataset. If we have transactions $T_1, T_2, ..., T_n$, the Merkle root M is computed as

$$M = H(H(T_1)||H(T_2)||H(T_3)|| ... ||H(T_{n-1})) \qquad (3)$$

This construction allows for efficient and secure verification that a transaction is part of the blockchain. The Merkle root is used in each block to ensure the integrity of transactions. Altering any transaction would change the Merkle root, thus invalidating the block:

$$M_{current} = SHA - 256(Merkle\ root\ of\ transactions) \qquad (4)$$

c. Nonce: The nonce is a random or pseudo-random number added to the block's data before hashing. The goal is to find a nonce such that the hash of the block satisfies certain conditions (e.g., the hash starts with a certain number of zeros).

$$H(BlockID||Merkle\ root||\ Timestamp||H_{prev}) < Target$$

Finding such a nonce is computationally difficult, making it a proof-of-work system. The complexity arises because there is no shortcut; the only way to find a valid nonce is through trial and error. The genesis block uses the nonce property to generate the initial block's hash. This process ensures that even if an attacker tries to tamper with the block, they would need to find a new valid nonce, which is computationally infeasible.

d. Random Integer Generation and Pairwise Hash Verification: Each voter generates a random integer, which is shared with a paired voter. Both voters then use this random integer and the Merkle root to authenticate each other. Let r be the random integer generated by voter i and r_j the integer generated by their paired voter j. The hash used for verification is:

$$\boldsymbol{H_{i,j} = SHA - 256}(Merkle\ root||\boldsymbol{r_i}||\boldsymbol{r_j}) \quad (6)$$

Voter $\boldsymbol{i}$ verifies voter $\boldsymbol{j}$ by checking if:

$$\boldsymbol{H_{j,i} = SHA - 256}(\boldsymbol{Merkle\ root}||\boldsymbol{r_j}||\boldsymbol{r_i}) \quad (7)$$

If the hashes match, the pair is verified. This pairwise verification ensures that each voter's identity and vote are validated by another voter, making it difficult for an attacker to forge votes without being detected. If an invalid or inconsistent hash is detected, the transaction is rejected.

Trusted Authority (TA) and Secure Registration

The TA acts as a centralized entity responsible for critical tasks such as voter registration, block creation, and voter authentication. Centralizing these tasks in a trusted and secure authority reduces the chances of unauthorized access or manipulation.

Voter registration requires the submission of at least two unique identification codes, such as a social security number and a phone number, which reduces the likelihood of double registration. The TA validates these details, ensuring that only legitimate voters are registered.

By creating secure accounts and associating them with unique identifiers, the system makes it difficult for attackers to impersonate or create fake identities.

The use of multiple unique identifiers makes it extremely difficult for an attacker to register multiple accounts, as they would need access to these identifiers for each account.

Centralized validation by the TA ensures that only genuine voters are allowed to participate, making unauthorized access nearly impossible.

Blockchain Structure

The blockchain structure used in the voting system ensures that each block contains unique BlockID, transactions, Merkle root, cryptographic hash, previous block's hash, and a timestamp.

The genesis block is the starting point of the blockchain, and it is uniquely identified by its BlockID and nonce, which are hashed using the SHA-256 algorithm.

Subsequent blocks are cryptographically linked, where each block contains the hash of the previous block, ensuring the integrity and immutability of the entire chain.

The cryptographic hash function (SHA-256) ensures that the content of each block cannot be altered without changing the hash. Since each block's hash is linked to the previous block, any attempt to tamper with a single block would require re-mining all subsequent blocks—a computationally infeasible task.

The Merkle root within each block further strengthens security by ensuring that any modification to a transaction within the block would change the Merkle root, thereby invalidating the block.

Since blocks are created by the TA, any unauthorized creation or modification of blocks by external or internal agents is highly unlikely.

Group-Based Voting and Authentication

Voters are split into groups, each containing 4 to 100 members. This grouping mechanism allows for efficient management of votes and ensures that each voter is authenticated by their peers within the group.

The use of an 8-character token (derived from the previous block's hash) for group authentication further ensures that only legitimate group members can participate in the voting process.

A 4-bit Merkle root value is randomly generated for each group, ensuring that the transactions within the group are securely linked and validated.

The peer-to-peer authentication process within the group ensures that each voter's identity is validated multiple times by different members, making it nearly impossible for an attacker to impersonate a voter.

The use of random tokens and Merkle roots adds an additional layer of security, as these values are unique and change with each transaction, making it difficult for an attacker to predict or reuse previous authentication data.

If any voter fails to authenticate correctly, the system automatically deregisters them, preventing any invalid transactions from being added to the blockchain.

Pairwise Authentication Using Hash Functions

After group authentication, each voter generates a random integer, which is shared with a paired voter. Each voter then derives a hash function based on the concatenation of the Merkle root and the generated random number. This process is used to authenticate the paired voter's input.

The system ensures that each voter can only have one transaction within the blockchain, preventing double voting or tampering with the voting process.

The use of pairwise authentication ensures that each vote is securely validated by multiple parties. The hash function derived from the Merkle root and random number is unique, making it extremely difficult for an attacker to reverse-engineer or forge the hash.

The computational difficulty of generating valid hash values that match the required criteria adds another layer of security, ensuring that only legitimate transactions are recorded in the blockchain.

Immutable and Tamper-Proof Blockchain

Once a block is added to the blockchain, it is immutable due to the cryptographic linkage between blocks (hash of the previous block).

The BlockID, Merkle root, and timestamp are concatenated and hashed to form the current block's hash, which is then linked to the next block. This chaining of blocks ensures the integrity and security of the entire voting process.

The immutability of the blockchain makes it resistant to tampering by both internal and external agents. Any attempt to modify a block would require altering all subsequent blocks, which would be computationally infeasible without controlling the majority of the network's hash power.

The use of secure cryptographic functions like SHA-256 ensures that even if an attacker gains access to the blockchain, they cannot alter the recorded data without detection.

5. Conclusion

The design of the system makes use of peer-to-peer authentication, cryptographic techniques, and the immutability of blockchain to produce a voting framework that is both highly secure and reliable. This system is immune to hacking attempts from both internal and external sources because it combines peer group authentication, centralized validation by the Trusted Authority, and the use of unique identification codes. The integrity and security of the voting process are preserved by the mathematical underpinnings of cryptographic hashing and the blockchain structure, which guarantee that any attempt to tamper with the system would be computationally impossible.

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A Semantic Ontology-Driven Explainable Classifier for Identifying *Plasmodium* Species and Stages in Thin Smear Images

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Abstract

This study presents an explainable classifier for identifying *Plasmodium* species and life stages from thin smear images by integrating **Convolutional Neural Networks (CNNs)** with **Pathogen Ontology**. Using the **CDC Thin Smear dataset**, the model applies **SegNet** for pixel-wise semantic segmentation, identifying features like infected red blood cells, ring forms, and gametocytes. Ontological reasoning maps visual features to structured biological concepts, producing interpretable outputs (e.g., "Parasitized: hasCleft AND hasDots"). This approach enhances diagnostic transparency, enabling clinicians to understand the AI's decisions. Additionally, **Grad-CAM** visualizations support explainability by highlighting relevant image regions, fostering trust in the system. The combination of deep learning and ontology ensures real-time, reliable malaria diagnostics, reducing human error while maintaining clinical relevance.
Keywords: Semantic segmentation, Ontology-based reasoning, Malaria diagnosis automation, XAI, Interpretable Classifiers.

1 Introduction

The detection of *Plasmodium falciparum* (Pf), the parasite responsible for severe cases of malaria, is a critical task in healthcare, particularly in malaria-endemic regions [1]. Traditionally, identification of *Pf* is performed through manual microscopic examination of blood smear images, which is labor-intensive, time-consuming, and subject to human error [2]. Automation of this process has gained momentum, with advances in machine learning, particularly Convolutional Neural Networks (CNNs), driving research in this domain [2] [3] [5]. A recent trend within this context is the use of ontology-based frameworks combined with CNNs, which aim to enhance the explainability and transparency of model decisions, crucial for healthcare applications where interpretability is essential [2].

Furthermore, integrating explainability into AI-driven malaria diagnosis is essential to build trust, ensure transparency, and enhance clinical decision-making [6]. While AI models can achieve high accuracy in detecting and classifying *Plasmodium* parasites, understanding the reasoning behind their predictions is crucial, especially in medical contexts where lives are at stake [6][7]. Explainable AI provides insights into which features, such as specific morphological or color patterns, influenced the diagnosis, allowing clinicians to verify the system's output [2][8]. This interpretability helps ensure that AI models are not making decisions based on irrelevant data or hidden biases, reducing the risk of misdiagnosis. Additionally, by offering clear, interpretable explanations, AI systems can facilitate collaboration between healthcare providers and AI tools, enabling clinicians to trust and confidently act on AI-generated insights [2].

To this end, current challenges faced by explainability techniques in AI-driven malaria diagnosis stem from the complexity of medical data and the intricacies of AI models [9]. Many deep learning models, particularly those used for image analysis, operate as "black boxes," making it difficult to interpret how they arrive at their decisions [8]. This lack of transparency becomes critical when diagnosing diseases like malaria, where a wrong diagnosis can have serious consequences[9]. Another challenge is ensuring that these explanations are relevant and reliable across diverse patient populations and environments, particularly in low-resource settings where training data might be limited[9][10]. Balancing model complexity with interpretability, while avoiding oversimplifications that could compromise diagnostic accuracy, remains a significant hurdle in integrating explainability into AI-driven healthcare solutions. This work is an effort towards providing models which can provide reliable and human understandable explanations as basis for their decisions.

2 Review of Related Literature

The identification of malaria parasites from thin blood smear images has traditionally relied on manual microscopic analysis. However, due to the inherent variability in image quality and the expertise required, several automated systems have been proposed [2]. For instance, [9] explored deep learning models to classify different stages of malaria parasites, using CNNs to achieve high accuracy. Their work demonstrated the utility of CNNs in handling complex biological images, enabling automatic detection of parasites and their life cycle stages. Similarly, [10] leveraged a CNN-based

model for *Pf* identification, achieving high accuracy with deep feature extraction. These methods, though effective, often function as "black-box" models, providing little insight into the decision-making process.

CNNs have shown remarkable success in medical image classification due to their ability to automatically learn hierarchical features from input images [11]. In particular, CNN architectures such as VGG, ResNet, and Inception have been widely applied in medical diagnosis tasks, including malaria detection from blood smears [6]. One of the key benefits of CNNs is their capacity to reduce the reliance on handcrafted features, a common challenge in traditional image analysis methods. Instead, CNNs automatically learn features at different levels of abstraction, allowing them to capture intricate patterns and structures within biological images [12].

Despite their efficacy, the use of CNNs in medical diagnostics faces a significant challenge in terms of interpretability. Medical practitioners demand transparent models that explain why certain decisions are made, which is particularly important when such decisions influence critical healthcare outcomes [13]. In this regard, ontology-based frameworks are becoming an important tool for augmenting CNN models with interpretability[14].

Ontology-based systems provide a formal representation of knowledge in a specific domain, making them ideal for tasks requiring structured data and reasoning [14]. In medical diagnostics, ontologies used to organize and represent complex biological knowledge, enhancing both the accuracy and transparency of decision-making systems. According to [15], ontologies in healthcare serve as a structured knowledge base, enabling the explanation of system outputs by linking decision-making processes to domain-specific knowledge. When applied to CNN models for malaria detection, ontology-based systems help enhance explainability by mapping learned features to known biological entities and processes. For example, [15] integrated an ontology-based framework with CNNs to explain model predictions by associating visual features with established clinical knowledge. Their study highlights that ontology-based systems can mitigate the black-box nature of CNNs, offering more transparent and interpretable models. Additionally, ontologies provide a mechanism for validating model predictions against domain knowledge, further enhancing trust in the automated system.

The combination of ontology and CNNs addresses this gap. By embedding domain knowledge in the form of ontologies, models can provide not only visual explanations but also logical reasoning aligned with the biological characteristics of *Plasmodium falciparum*. For instance, [16] proposed a hybrid ontology-based CNN system for malaria detection, wherein ontologies provided the underlying reasoning that complemented the model's visual output, leading to a more transparent and reliable system.

While ontology-based CNN models show promise in improving the identification of *Plasmodium falciparum*, several challenges remain. One key challenge is the development of comprehensive ontologies that accurately represent the complex biological structures and life cycles of malaria parasites [15]. Another challenge is the integration of these ontologies with deep learning models without compromising model performance. Furthermore, there is a need for robust evaluation frameworks to assess the interpretability and explainability of ontology-based CNN models, especially in high-stakes medical scenarios [17][18].

3 Methodology

Using the Kaggle Malaria dataset, which contains labeled images of red blood cells infected with *Plasmodium falciparum* and healthy cells of around 27,558 images across two classes: parasitized and uninfected, a Convolutional Neural Network (CNN) with an input layer for 64x64x3 images, followed by 3 convolutional layers with 32, 64, and 128 filters (each using 3x3 kernels), ReLU activation function, and 2x2 max-pooling after each convolution, two fully connected layers (e.g., 256 and 128 neurons), followed by a softmax output layer for binary classification (infected vs. healthy cells), with dropout (e.g., 0.5 rate) and batch normalization to prevent overfitting and stabilize learning is trained on this dataset. To ensure proper training, we pre-processed the images by normalizing pixel values and augmenting the dataset to improve generalization.

Next, we incorporate the Pathogen Ontology, a structured framework of biological knowledge that categorizes pathogens, including *Plasmodium falciparum*. This ontology helps us align our model with relevant biological concepts, integrating domain knowledge into the AI model's learning process. By associating model outputs with the corresponding pathogen class in the ontology, we can map the prediction of the CNN to the biological meaning, aiding in interpretability.

To enhance explainability further, we employ Grad-CAM (Gradient-weighted Class Activation Mapping), a technique that visualizes the areas of input images that the CNN uses to make its predictions. By applying Grad-CAM to the trained classifier, we can produce heatmaps over the images, highlighting the regions of red blood cells where the model "looks" to identify *Plasmodium falciparum* infection[22]. These visualizations allow medical professionals to verify whether the model focuses on biologically relevant regions, such as certain parts of infected cells, making the system more transparent and trustworthy in real-world diagnostic scenarios.

4 Proposed Method

a) *Define C = { $c_1, c_2, ... c_n$}, the classes from the ontology which serve as the output of the classification.*

b) *Define D = {d | ∃ c ∈ C, d ≡ c is a valid axiom of the ontology} i.e. definitions of concepts in the ontology*

Let P: be a set of concepts (features) in the ontology involved in D.

Let R: be a set of relationships such as R = {r | r =relationship(p), p ∈ P }

Let F: be a set of ontological features f ∈ F, that is the triplets (c, p, r) in D which will be used to explaining the classification.

c) *Build a set FI ⊆ F of ontological features that match the features of the data point input to the classifier such that FI = {fi ∈ F | fi ≡ ∃ p.r }*

d) *Build an ontological reasoning from D and FI such that CI ⊆ C, for the classified data point c_i.*

e) *apply DI ⊆ D such that DI = {di ≡ ci } and FI to generate an explanation for CI.*

It is important to note that step (c) refines step (b), as constructing **F** with ontological features that cannot be extracted from the classified data would be ineffective. Additionally, the abstraction level of the explanations is inherently connected to the abstraction level of the ontological features used. Indeed, the refinement of features ensures that only **ontological elements that can be reliably extracted from thin smear images** are included in the model's explanations. It would be inefficient to incorporate features that the classifier cannot detect, such as cellular structures beyond what the microscope captures. The **abstraction level of explanations corresponds to the granularity of the ontological features**—for example, the model can explain that a region contains **P. falciparum** because it detects a **ring form or gametocyte**, but it cannot further explain the molecular composition of these forms. This reflects a broader principle in explainable AI: **at some level of abstraction, explanations are deemed sufficient** without needing deeper detail. Similar to other models combining CNNs and ontologies, the malaria classifier connects image-based outputs (e.g., identifying parasites) with **semantic labels** from the pathogen ontology, ensuring explanations are understandable and clinically useful without attempting to define underlying biological processes [20].

5 Explanation Pipeline

This section outlines the implementation of our approach, which consists of two primary modules. The first is a **semantic segmentation (DL) module**, responsible for extracting ontological features from the input image. The second is an **ontological reasoning module**, referred to as **OntoClassifier**, which computes the set of classes (**CI**) that can be inferred from the identified features (**FI**) while generating corresponding explanations [19]. The design of these modules is detailed as follows:

Semantic Segmentation

The **semantic segmentation process** plays a crucial role in identifying and classifying specific regions within microscopic blood smear images. The objective is to analyze thin smear images to detect **Plasmodium species** (e.g., *P. falciparum*, *P. vivax*) and distinguish between infected and uninfected red blood cells (RBCs). Each pixel in the image is labeled to correspond to a meaningful biological class, such as parasite types, healthy cells, or background. To achieve this, the segmentation process uses the **SegNet architecture**, which is well-suited for pixel-wise labeling, ensuring that every part of the image is accounted for. This segmentation is not merely visual but also integrates semantic meaning through **pathogen ontology**, making the results explainable to clinicians.

The **SegNet architecture** is employed as the core model for the semantic segmentation task. It consists of an **encoder-decoder network** that reduces the input image's dimensions through max-pooling operations (in the encoder) to extract key features and then upsamples them (in the decoder) to reconstruct the segmentation mask. This structure ensures that important spatial information is retained while achieving efficient pixel-level classification [19]. The **CDC Thin Smear dataset** is used to train the SegNet model, with annotated images containing examples of both **infected and uninfected RBCs**. The dataset provides detailed masks indicating the presence of parasites, specific *Plasmodium* species, and background regions, which are essential for training the model to distinguish subtle visual features. By correctly segmenting the microscopic regions, the model provides granular insights into the health status of each RBC in the sample [21].

The integration of **Pathogen Ontology** ensures that the segmentation results carry **semantic meaning** and are aligned with established biomedical knowledge. Once the SegNet model segments the regions corresponding to different parasite species or uninfected cells, these segmented areas are **mapped to ontological terms** that represent the biological identity of each structure (e.g., NCBITaxon:5833 for *P. falciparum*). This mapping ensures that the predictions are not only accurate but also meaningful within a clinical and scientific context . The use of pathogen ontology provides **explainability**, making the model's output interpretable to clinicians by linking segmented areas to standardized biological identifiers. This semantic segmentation process supports **diagnostic transparency** by clarifying which regions contributed to the classification, thereby enhancing trust and enabling more informed decision-making in malaria diagnosis. This is presented in figure 1
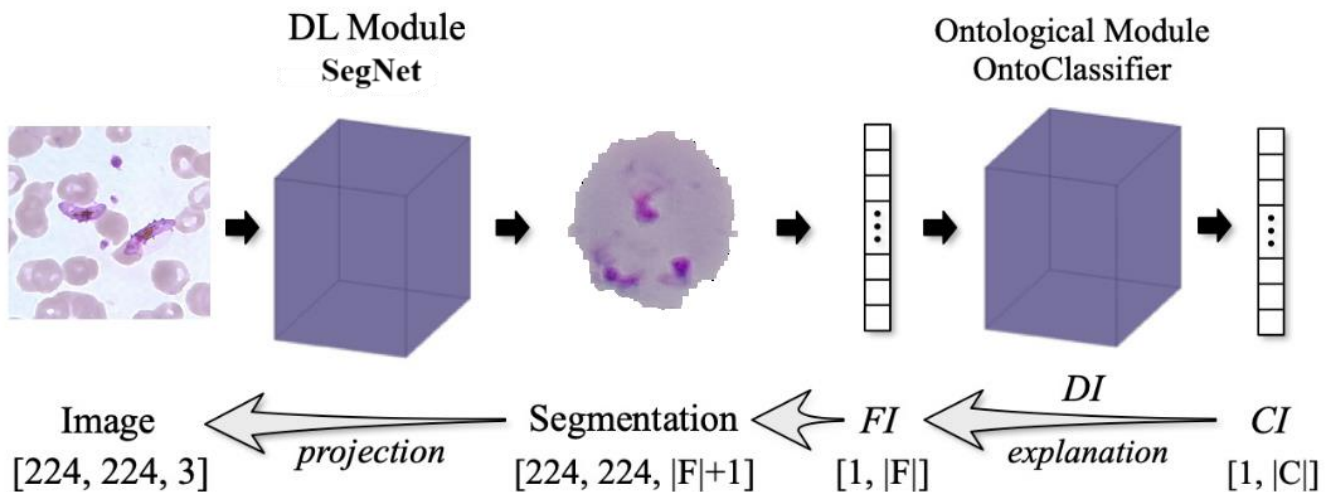

Figure 9: Architecture of the Ontologically explainable classifier [19].

OntoClassifier

The presence of pixels in a segmentation layer signifies the existence of a corresponding ontological feature. That is why the semantic segmentation process utilizes a Convolutional Neural Network (CNN) to analyze thin smear images, identifying ontological features such as **ring forms, schizonts, and gametocytes** as individual pixels in the segmentation mask. Each detected pixel is associated with an ontological assertion (e.g., (∃ **hasFeature . parasite**)), allowing the classifier to compile a set of satisfied assertions (**FI**) for each image. The model then employs a reasoning mechanism using a defined set of relationships from the **Pathogen Ontology** to deduce the corresponding classes (**CI**) that accurately label the image, such as identifying **P. falciparum** based on the observed features. While traditional methods for ontological reasoning can be slow and resource-intensive, this classifier effectively integrates deep learning capabilities with ontological mapping to ensure efficient, real-time classifications while maintaining explainability in identifying specific malaria parasites.
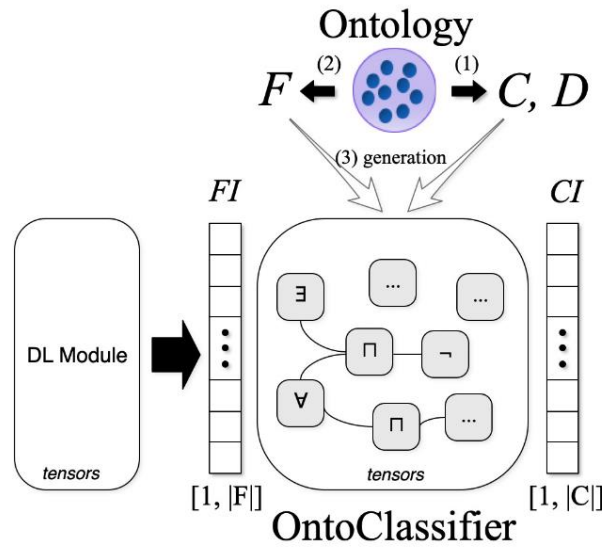
Figure 11: Structure for Generating an OntoClassifier [19]

6 Result

The result presented here are three instances from CDC dataset as outlined above. Two of the test cases are parasitized while one is non-parasitized. The explanations generated are based on the structured of the pathogen ontology and the result of semantic segmentation.
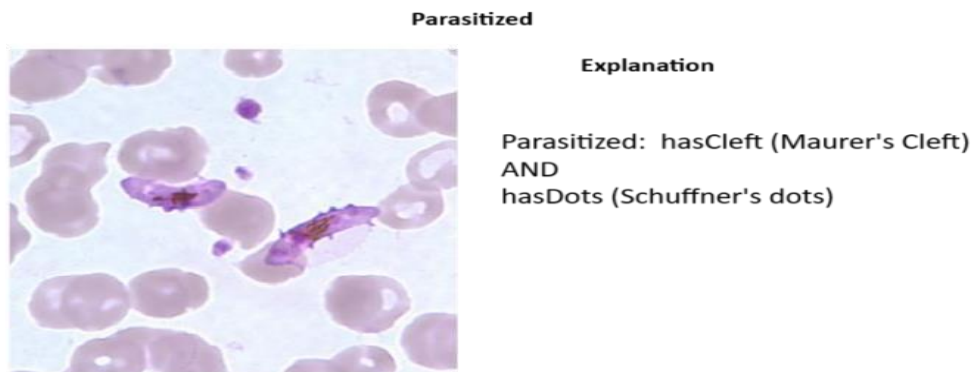

Figure 12: Example of Parasitized Input Image and the corresponding Output Explanation

From figure 3, the explanation "Parasitized: hasCleft (Maurer's Cleft) AND hasDots (Schuffner's Dots)" signifies that the ontology-based explainable model has analyzed the thin smear image and identified specific morphological features indicative of Pf infection. During the segmentation process, the model utilizes deep learning techniques to accurately detect regions within the image where Maurer's clefts, which are associated with the developmental stage of the parasite, and Schuffner's dots, which appear in infected red blood cells, are present. By referencing a defined ontology that links these features to their corresponding biological terms, the model classifies the image as "Parasitized." The assertion "hasCleft AND hasDots" indicates that both features are observed, suggesting a more detailed characterization of the infection and allowing clinicians to understand the specific pathological changes associated with the malaria parasite in

the examined sample. This reasoning integrates visual analysis with semantic knowledge, providing a meaningful and clinically relevant output.
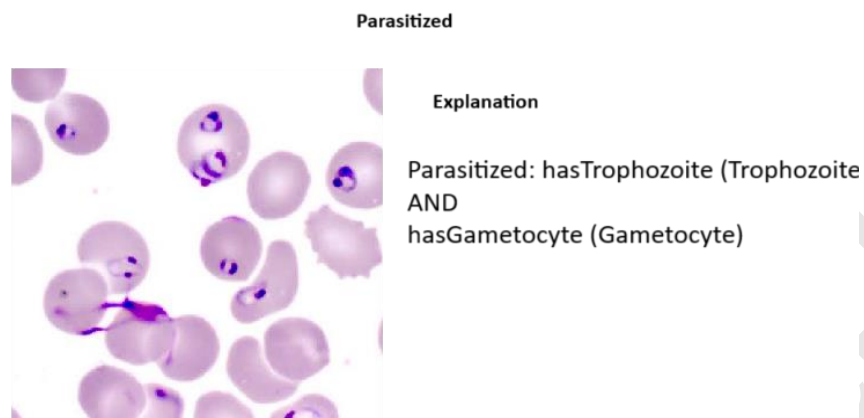
Parasitized

Explanation

Parasitized: hasTrophozoite (Trophozoite AND
hasGametocyte (Gametocyte)

Figure 13: Another example of a Parasitized Image Input and a Corresponding Explanation

From Figure 4 the explanation "Parasitized: hasTrophozoite (Trophozoite) AND hasGametocyte (Gametocyte)" indicates that the ontology-based explainable model has identified specific features within the thin smear image corresponding to two distinct stages of the Plasmodium species lifecycle. The model first segments the image into various regions using a semantic segmentation approach, detecting individual pixels associated with infected red blood cells. It recognizes the presence of trophozoites, which are the active feeding stage of the parasite, as well as gametocytes, which are the sexual forms that can be taken up by mosquitoes. By leveraging a predefined ontology that defines these relationships, the model classifies the image as "Parasitized" based on the detection of both features. The logical assertion "hasTrophozoite AND hasGametocyte" reflects that both stages are present in the analyzed image, allowing for a comprehensive understanding of the infection status and the specific life cycle stages of the parasites present. This reasoning process combines visual data with semantic knowledge from the ontology, ensuring an interpretable and clinically relevant classification.
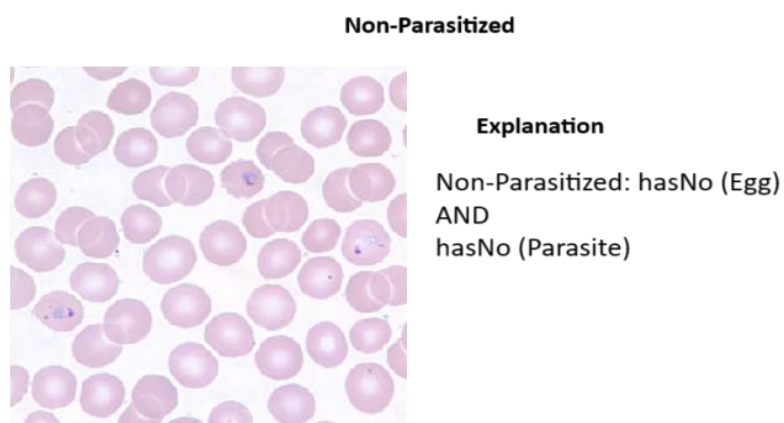
Non-Parasitized

Explanation

Non-Parasitized: hasNo (Egg)
AND
hasNo (Parasite)

Figure 14: Example of Non-Parasitized Input Image with Corresponding Explanation

From Figure 5, the output "Non-parasitized: hasNo (Egg) AND hasNo (Parasite)" indicates that the ontology-based explainable model has analyzed the thin smear image and determined that it does not contain any signs of malaria

infection. During the semantic segmentation process, the model examines the image for specific features that would indicate the presence of parasites, such as Plasmodium species or their developmental stages (like eggs). In this case, the model successfully identifies that there are no egg structures and no parasites present in the segmented regions of the image. By utilizing a predefined ontology, the model classifies the image as "Non-parasitized" based on the logical assertions "hasNo (Egg) AND hasNo (Parasite)," confirming the absence of any parasitic infection. This output provides a clear and interpretable result for clinicians, indicating that the thin smear does not show evidence of malaria, which is essential for accurate diagnosis and treatment decisions.

Conclusion

The integration of ontology-based systems with CNN models offers a promising avenue for the development of explainable AI in medical diagnostics, particularly for malaria detection. By providing structured knowledge and reasoning frameworks, ontologies enhance the transparency and interpretability of CNN predictions, addressing one of the key challenges in the application of deep learning in healthcare. As research in this area advances, ontology-based explainable models have the potential to significantly improve the accuracy, trust, and reliability of automated malaria detection systems.

Future research should focus on refining ontology frameworks, enhancing their alignment with CNN-based feature extraction, and developing standardized evaluation metrics for explainability in medical AI systems. Additionally, efforts should be made to ensure that ontology-based systems can scale across different diagnostic tasks and medical conditions, thereby broadening their applicability.

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An Adaptive and Scalable Ontology for Explainable Deep Classifier in Disease Surveillance

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Abstract. This research aims to improve explainability of predictions in disease surveillance by leveraging an ontology-based model. A Markov Decision Process (MDP) and a Q-Learning algorithms were proposed to update two public Ontologies making them both dynamic and Scalable in order to enhance the quality of explanations generated on the output of a deep learning classifier used for Morbidity/Mortality prediction of Malaria disease. The study uses Atlas Malaria dataset, OBO Malaria Ontology, SWEET Ontology and a Recurrent Neural Network thus, integrating domain-specific knowledge and data. The study compares the proposed model with a static model based on fidelity, interpretability, relevance, ROC and AUC metrics. The proposed model **achieves a fidelity score of 0.92**, compared to **0.75** for the static model, along with a **higher interpretability score of 4.7/5** versus **3.9/5** for the static approach. Additionally, the **relevance score** for the dynamic ontology is **0.88**, outperforming the static model's **0.72**. The dynamic ontology also exhibits superior classification performance, with an **AUC of 0.9532**, significantly higher than the static model's **AUC of 0.7968**. These results demonstrate the dynamic ontology's effectiveness in improving both model performance and explanation quality in case studied.

Keywords: Evolving knowledge graphs, White-box AI, Semantic network, Ethical AI, Clarity, Public Health Surveillance.

1 Introduction

In the context of Artificial Intelligence (AI), explainability refers to the ability of a model to provide details or reasons to make clear how and why it made a specific decision or prediction. Explainability in AI systems boosts trust, transparency, and accountability by making them more understandable to users, decision-makers, and regulators [1]. It ensures fairness, detects biases, and improves model reliability. In fields like healthcare, security, finance, and law, explainability is crucial for validating AI's safety and ethical use [2]. It also fosters better human-AI collaboration, allowing users to refine, correct, and improve models, leading to more robust and trustworthy AI applications. Furthermore, it also allows for transparent, interpretable insight, ensuring evidence-based interventions [3]. For example, when an AI model predicts an imminent outbreak, explainability helps epidemiologists understand the factors driving the prediction, such as symptoms, environmental factors, or human mobility patterns. This transparency is essential for making informed decisions about public health measures. Furthermore, Explainable AI addresses ethical concerns in disease surveillance by identifying and mitigating biases in data. Whence, Black-box models can lead to unfair targeting of certain populations or regions. Explainable AI enhances accountability by allowing stakeholders to trace back AI decisions, justifying actions during health crises. This trust in AI-driven public health tools encourages their wider adoption and integration into real-time disease surveillance systems, thereby reducing the risk of biased decisions.

Ontology is a tool that is used in explainable AI to provide structured, domain-specific knowledge. This approach provides context-aware interpretations of AI decisions, especially in complex domains like healthcare, law, and scientific research. Ontologies also improve the consistency and transparency of AI models by aligning predictions with domain knowledge, reducing errors or biases [4]. Ontology-based explanations also facilitate better communication between AI systems and human experts, ensuring understandable and actionable reasoning behind AI decisions.

Despite their benefits, ontology-based explainable classifiers face challenges related to scalability and dynamism [5]. Large, static ontologies can become outdated and cumbersome to manage, particularly when integrated with high-dimensional AI models in real-time surveillance systems [6][7]. This can lead to computational inefficiencies, slowing down the decision-making process, which is critical in the context of disease outbreaks. Additionally, the dynamic nature of disease surveillance, where new diseases or emerging variants continually shift the landscape, requires ontologies to be updated regularly [8][9]. Managing these updates in real time is a significant technical challenge, as outdated ontologies could lead to incorrect or irrelevant predictions [10]. For example [11], posited that future research in this area could focus on developing more adaptive ontology management systems that can evolve alongside AI models, ensuring that both remain accurate and relevant in rapidly changing environments.

This study aims to create an adaptive and scalable Ontology for Mobidity/Mortality risk prediction for Malaria disease, ensuring adaptability and reliability in response to evolving disease dynamics. It aims to enhance transparency, trust, and decision-making by providing domain agreed, context-aware explanations, reducing bias, and promoting fairness in AI-driven decisions.

2 Review of Literature

In disease surveillance, artificial intelligence (AI) has become an indispensable tool for predicting outbreaks, identifying high-risk areas, and managing public health resources [10]. However, the increasing complexity of AI systems necessitates improved transparency and interpretability, since decisions based on these AI predictions can have lives-affecting consequences [12]. Explainable AI (XAI) aims to make the decision-making process of AI systems more understandable to humans, enhancing trust and accountability [13]. Ontologies as structured representations of domain-specific knowledge, are increasingly being explored as a means of improving the explainability of AI classifiers [14][15]. These knowledge-based systems can provide deeper, more contextually relevant explanations, which are especially useful in disease surveillance, where understanding the factors driving predictions is essential for timely and accurate public health interventions [16].

Other explainable AI methods used in disease surveillance, such as model-agnostic techniques like LIME, SHAP, or feature importance analysis like Heap-maps, have notable weaknesses compared to ontology-based approaches [17][18][19]. These methods often focus on explaining individual predictions based on correlations or approximations between input and output rather than leveraging structured domain knowledge, which can lead to explanations that lack context or domain relevance [22]. For example, in disease surveillance, these methods might indicate that certain symptoms or demographic features contribute to a prediction without providing deeper insights into how these factors interact within the disease transmission process. Additionally, model-agnostic methods may struggle with transparency in complex, high-dimensional models like deep neural networks, offering only superficial or generalized explanations that may not align with public health expertise [23] [24]. This can lead to a disconnect between the AI model's outputs and the actionable insights needed for effective disease control, making it harder for public health professionals to trust and act on the predictions.

Ontologies have long been used in healthcare for organizing and standardizing medical knowledge [25][26]. Resources such as OBO Foundry, SNOMED CT, ICD-10, and MeSH offer structured ways of representing symptoms, diagnoses, and treatments, enabling better data interoperability across healthcare systems [21]. In the context of AI, ontologies serve as a foundation for integrating domain knowledge directly into classifiers, enhancing the interpretability of their decisions [6]. In disease surveillance, ontologies can be used to represent relationships between symptoms, transmission vectors, environmental factors, and other epidemiological variables, providing AI models with a robust framework for classifying diseases and predicting outbreaks [27]. For instance, during the COVID-19 pandemic, ontology-driven models helped integrate real-time clinical data with historical outbreak patterns to better understand the spread of the virus and inform intervention strategies [10].

Traditional XAI methods like LIME and SHAP have been applied in disease surveillance to make AI predictions more transparent [13]. However, these methods often fall short when it comes to providing domain-specific explanations, relying heavily on statistical correlations rather than leveraging expert knowledge. Ontology-based classifiers offer a solution by embedding structured knowledge directly into AI models, allowing for explanations that are both context-aware and grounded in epidemiological expertise. For example, an ontology-driven AI system might classify a region as high-risk for a disease outbreak based on a combination of environmental factors, human mobility patterns, and local healthcare capacity. By explaining these relationships in terms that align with established disease transmission models, ontology-based systems provide public health officials with clearer insights into the factors driving AI predictions [16]. Research in this area demonstrates that such explanations can lead to more actionable and informed decisions, such as targeted vaccination campaigns or resource allocation [20].

Scalability is a significant challenge when using ontologies for explainable AI, particularly in large, dynamic domains like disease surveillance. Ontologies, which represent domain knowledge through structured concepts and relationships, can become exceedingly complex as the scope of the domain expands. Managing and querying large ontologies in real-time can lead to performance bottlenecks, especially when integrated with deep learning models that process vast amounts of data. As ontologies grow, the computational resources required to maintain and utilize them also increase, posing difficulties for systems that need to provide quick, on-demand explanations. Additionally, integrating large ontologies with high-dimensional machine learning models requires sophisticated optimization techniques to ensure that the AI system remains efficient and scalable.

Dynamism is another issue, as ontologies must evolve with changing knowledge and real-time data. In fast-moving fields like disease surveillance, where new diseases, symptoms, or environmental factors constantly emerge, static ontologies

quickly become outdated. AI models relying on such ontologies may produce explanations that no longer align with the latest scientific understanding or surveillance data. Maintaining up-to-date and relevant ontologies requires systems that can dynamically adjust and incorporate new information without manual intervention. This introduces further complexity in the form of real-time ontology updating, knowledge reconciliation, and conflict resolution, which are necessary to ensure that AI systems continue to provide accurate and reliable explanations as the underlying knowledge base evolves.

Ontology-based explainable classifiers represent a promising approach for enhancing transparency and trust in AI systems used for disease surveillance. By grounding AI models in structured, domain-specific knowledge, these classifiers provide explanations that are both interpretable and contextually relevant to public health professionals. This enables more accurate, trustworthy, and actionable decision-making, particularly in high-stakes situations like epidemic outbreaks [16][28]. However, challenges related to scalability and the dynamic updating of ontologies remain significant, highlighting the need for further research in creating adaptable, scalable systems that can evolve with emerging health threats [6][29].

3 Data and Methods

This work aims to develop a dynamic **ontology** to provide explanations for deep learning classifier models, such as **Recurrent Neural Networks (RNNs)**, specifically for **morbidity/mortality risk prediction tasks for Malaria disease**. The model will uses **Malaria Ontology** and **Semantic Web for Earth and Environment Technology (SWEET) Ontology to build an ontology-based explanations** model which provide explanations on features warranting for the classicification, focusing on why certain individuals are at higher risk of mobidity or mortality.

Data gathered from reliable sources, such as news reports on **disease burden**, **prevalence**, and **mortality rate** across different geographical locations, are used to keep the **Malaria Ontology** and **Semantic Web for Earth and Environment Technology (SWEET) Ontology** updated. These ontologies serve as the knowledge base, enabling the system to interpret and explain the factors influencing the prediction of the classifier.

To ensure the ontologies remain adaptable **and scalable**, a **Q-learning algorithm** is developed. This algorithm decides when and how to update the ontologies based on a utility function it learns over time. By weighing the benefits of updating the ontology against potential system overload or irrelevant changes, that will help the system to maintain efficiency and accuracy in prediction. This ensures a more adaptable and explainable deep learning system that can dynamically adjust to new data and evolving disease patterns. Hence, this is presented in figure 1.
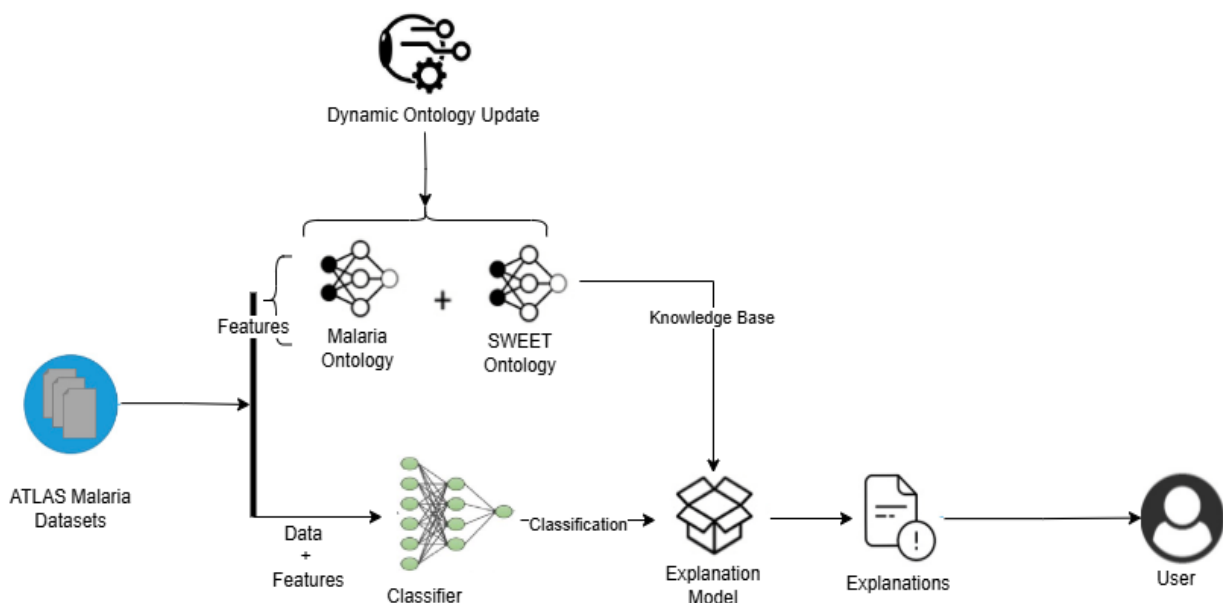

Figure 15: Dynamic Ontology Update Mechanism

Dataset/Ontologies

1. **Atlas Project Malaria Data**

   This dataset provides comprehensive global maps and data related to malaria transmission, prevalence, incidence and environmental factors that affect mosquito populations, with a strong focus on sub-Saharan

Africa. The dataset is widely used in predictive models for malaria transmission, hotspot identification, and mortality/morbidity risk classification.

URL: https://data.malariaatlas.org/

2. **Malaria Ontology**:

The **Malaria Ontology** focuses on malaria-related knowledge, including the biology of the *Plasmodium* parasite, mosquito vectors, clinical manifestations, treatment, and prevention strategies. It organizes and standardizes data for malaria research and interventions, making it easier to analyze and integrate data from different sources.

URL: http://purl.obolibrary.org/obo/IDOMAL_0002350

3. **Semantic Web of Earth and Environment Terms (SWEET) Ontology**:

The **SWEET Ontology** is a comprehensive framework for representing Earth and environmental sciences, including geophysical phenomena, climate, and ecosystems. It supports integration and sharing of environmental data across domains by providing a common vocabulary. SWEET is essential for projects related to climate change, environmental monitoring, and sustainability, ensuring interdisciplinary data can be effectively linked and understood.

URL: https://www.earthdata.nasa.gov/community/sweet

4 Methods

Problem Definition:
- Let S be the state space, where each state $s \in S$ represents a specific state of the ontology (e.g., concepts, relationships, structures).
- Let A be the action space, where each action $a \in A$ corresponds to a potential modification of the ontology (e.g., adding, modifying, or deleting concepts/relations).
- The agent's goal is to find a policy $\pi : S \to A$, which maximizes the expected cumulative reward R, by updating the ontology dynamically as new data becomes available.

Markov Decision Process (MDP):
- **State**: $s_t \in S$ at time t, representing the current state of the ontology.
- **Action**: $a_t \in A$, an action which modifies the ontology's structure at time t.
- **Transition Function**: $T(s_{t+1}|s_t, a_t)$ represents the probability of moving from state s_t to state s_{t+1} after taking action a_t.
- **Reward**: $r_t = R(s_t, a_t)$, a scalar reward obtained after taking action a_t in state s_t.

Q-Learning Algorithm

The Q-learning algorithm will be used to learn an action-value function Q(s, a), which represents the expected cumulative reward of taking action *a* in state *s*, and following the optimal policy thereafter. The algorithm is presented below:

1. **Initialize the Q-table**:

$$Q(s,a) \leftarrow 0 \quad \forall s \in S, \forall a \in A$$

2. **Policy**: An ϵ-greedy policy is used to balance exploration and exploitation:

$$a_t = \begin{cases} \text{random action with probability } \epsilon, \\ \max_a Q(s_t, a) \text{ with probability } 1 - \epsilon \end{cases}$$

3. **Q-Value Update**: After taking action a_t in state s_t, receiving reward r_t, and observing the next state s_{t+1}, the Q-values are updated as follows:

$$Q(s_t, a_t) \leftarrow Q(s_t, a_t) + \alpha[r_t + \gamma \max_a Q(s_{t+1}, a) - Q(s_t, a_t)]$$

where:

- $\alpha \in [0,1]$ is the learning rate,
- $\gamma \in [0,1]$ is the discount factor,
- $\max_a Q(s_{t+1}, a)$ is the maximum Q-value for the next state s_{t+1}, which corresponds to the best possible future action.

4. **State Transition**: The next state s_{t+1} is determined by the transition dynamics of the environment:

$$s_{t+1} \sim T(s_{t+1} | s_t, a_t)$$

In this case, this refers to the ontology being updated based on the action a_t, and how the new data or structural modification impacts the ontology.

5. **Termination**: The process repeats until a terminal state or the end of a predefined number of episodes, after which the Q-values reflect the optimal policy.

5 Results

The performance of the system was assessed using algorithmic and human centered metrics. For the algorithmic metrics, **Receiver Operating Curve (ROC) and Area Under Curve (AUC)** were used while for the human centered metrics: **Fidelity, Interpretability**, and **Relevance**. The results are presented below:
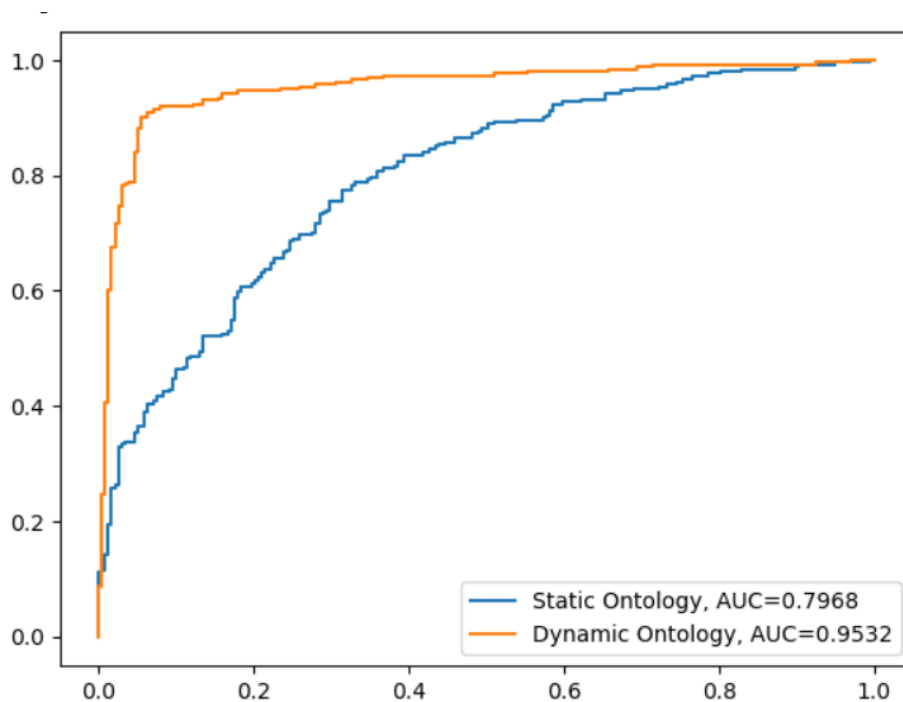

Figure 16: Comparision of the proposed dynamic ontology and static ontology

From Figure 2 above, the ROC curve compares the proposed model with static model: the **Static Ontology** (blue curve) and the **Dynamic Ontology** (orange curve), with the **AUC (Area Under the Curve)** as the primary performance metric. The **Static Ontology** classifier yields an **AUC of 0.7968**, indicating moderate classification capability, but it struggles to minimize false positives while maintaining high true positive rates, as reflected by the curvature away from the top-left. The **Dynamic Ontology** classifier significantly outperforms the static version, with an **AUC of 0.9532**. This higher AUC demonstrates the model's ability to more accurately balance between detecting true positives and minimizing false positives across thresholds. The curve for the dynamic model approaches the ideal performance boundary, suggesting better discriminative power and reduced error rates. Thus, the dynamic ontology-based approach shows superior classification performance, offering more reliable predictions.

Human Centered Evaluation

Fidelity

Fidelity refers to how accurately the explanations generated by the ontology reflect the decision-making process of the deep classifier. Thus, high fidelity indicates that the ontology explanations closely match the classifier's internal logic, making the model's decision-making transparent and understandable. Here, fidelity was quantified using a fidelity score that represents the proportion of cases where the explanation matched the classifier's output. The Proposed system achieved an average **fidelity score** of **0.92 compared to 0.75 achieved by the static model**. This means that the dynamic ontology-based explanations accurately represented the decision-making process in 92% of the cases, closely aligning with the classifier's outputs. This high fidelity score suggests that the system reliably mirrors the model's reasoning, allowing users to trust the explanations as faithful representations of the classifier's predictions.

Interpretability

Interpretability measures how understandable the explanations are to human. The goal was to ensure that the explanations could be easily interpreted and applied in real-world disease control settings. A group of 20 individuals were asked to evaluate the interpretability of explanations generated by the ontology system. Each individual reviewed 10 disease detection cases and rated the interpretability on a Likert scale from 1 (very difficult to understand) to 5 (very easy to understand). The average **interpretability rating** was **4.7/5 compared to 3.9/5 for the static based ontology system**, indicating that the majority of individuals found the explanations to be highly understandable and actionable. Participants noted that although both ontology's explanations provided clear terms, the dynamic system provided concise rationales behind the deep classifier's decisions, particularly in identifying up to date correlations between symptoms, demographics, and disease risk factor of individuals.

Relevance

An explanation is considered relevant if it provides actionable insights that enhance the user's understanding of the underlying data and model predictions. The relevance of explanations was assessed by analyzing feedback from users. A relevance score was computed based on the proportion of cases where a user deemed the explanations directly applicable to model decision process. An average **relevance score** of **0.88 outperforming the static model which achieved a relevance score of 0.72**, indicating that 88% of the explanations provided meaningful and applicable insights for disease surveillance.

The Performance of the two systems in all the three human centered metrics, are summarized in Table 1 below.

Metric	Dynamic Ontology Explanations	Static Ontology Explanations
Area Under Curve	0.9532	0.7968
Fidelity	0.92	0.75
Interpretability	4.7/5	3.9/5
Relevance	0.88	0.72

Table 1: Comparative performance of Dynamic ontology-based explanations versus traditional Static methods.

6 Discussion

The results demonstrate the efficacy of the proposed Dynamic and Scalable ontology-based explanation framework in improving the transparency and usability of deep classifiers in disease surveillance. The model's accuracy and high fidelity score ensures that the explanations accurately reflect the classifier's internal logic, while the interpretability and relevance metrics confirm that the system provides understandable and useful insights for users. Furthermore, the system guarantees alignment with domain knowledge since the ontologies are domain agreements.

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Comparative Analysis of Machine Learning Models for Enhancing Cybersecurity on Cyber-physical Systems in Smart Grids Against DDoS Attacks

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Abstract. Detecting Distributed Denial of Service (DDoS) attacks in cyber-physical systems, particularly smart grids, requires highly accurate and efficient solutions. This study evaluates the performance of several machine learning algorithms, including Logistic Regression, Naive Bayes, K-Nearest Neighbors, Decision Trees, Support Vector Machine, Random Forest, Gradient Boosting Machines, XGBoost, Artificial Neural Networks, and Recurrent Neural Networks for detecting DDoS attacks. The CICIDS2017 dataset, which includes real-world attack scenarios, was used for training and testing. The evaluation metrics, such as precision, recall, accuracy, and F1-score, demonstrate exceptional performance across most algorithms, with XGBoost achieving perfect scores on all metrics. Other models, such as RF, DT, and GBM, also show near-perfect performance, while simpler models like Naive Bayes, though slightly lower, still provide viable detection capabilities. These results emphasized the importance of advanced machine learning algorithms in ensuring the security and stability of critical infrastructure like smart grids.

Keywords: Cyber-physical Systems, DDoS, Machine Learning, Smart Grids

1   Introduction

Smart grids are a vital component of modern cyber-physical systems (CPS). They integrate information and communication technology (ICT) into electrical power networks, ensuring efficient and reliable energy distribution [1]. However, this convergence of digital and physical systems also introduces vulnerabilities, particularly in cyberattacks such as Distributed Denial of Service (DDoS) [2]. A DDoS attack aims to overwhelm communication networks or services by flooding them with excessive traffic, thereby disrupting normal operations [3].

Machine learning (ML) models offer significant potential for detecting these attacks by identifying patterns and anomalies within network traffic data [4]. The critical challenge is selecting and evaluating the most effective classification algorithms that can function in real time and accurately detect DDoS attacks without compromising the smart grid's performance [5].

In this paper, we present an experimental analysis of ten machine-learning classification algorithms used for DDoS detection on cyber-physical system in smart grids. These algorithms were evaluated based on crucial performance metrics: precision, recall, accuracy, and F1-score. The primary objective is to identify the most effective algorithm for enhancing DDoS detection and strengthening the cyber-physical system security in smart grid.

2 Related Work

This review assesses various studies on cyber-physical systems (CPS) and smart grid environments, focusing on detecting and mitigating Denial of Service (DoS) and Distributed Denial of Service (DDoS) attacks using a range of machine learning and statistical techniques.

[6] combined rule-based and machine-learning methods for detecting DDoS attacks in CPPS, achieving a weighted accuracy of 98.71% and real-time solid performance. Future research is needed to extend its applicability to broader contexts.

[7] introduced a Hierarchical Bayesian Network (HBN) model enhanced by bacterial foraging optimization (BFO) to defend CPS against DoS attacks. The model achieved high accuracy (98.4%) and low RMSE (0.0617), demonstrating scalability for large-scale CPS. However, its computational demands are a significant limitation.

[8] proposed a hybrid machine-learning technique for detecting DDoS attacks in smart grids. The technique achieves 83.23% accuracy with moderate precision, recall, and F1-score. Despite its novel approach, the model requires substantial improvements in precision and recall.

[9] used Decision Tree, Random Forest, K-Nearest Neighbors and PCA for DDoS detection in Industry 4.0 CPPS, achieving near-perfect accuracy and F1-scores. The study highlighted the superior performance of supervised models but noted challenges in unsupervised learning.

[10] proposed a sequential supervised machine learning approach using a two-layer hierarchical Random Forest Classifier (RFC) for cyber-attack detection in smart grids. The model achieved 95.44% accuracy, effectively handling data imbalance and feature reduction, but preprocessing improvements are necessary.

[11] explored ensemble learning methods for anomaly detection in smart grids, with stacking-based ensembles achieving the highest accuracy (97.3%). Despite their effectiveness, the models' complexity and varying performance across methods pose challenges.

[12] developed a machine learning-based detection model for DoS attacks in smart grids, employing SVM, Decision Tree, and Naive Bayes classifiers. The model showed strong performance with precision, recall, and F1-score all at 0.97, though further refinement is needed.

[13] focused on enhancing SCADA system security against DDoS attacks using Naive Bayes, J48 and Random Forest algorithms. Random Forest showed the highest accuracy (99.99%), but the study's reliance on the KDDCup'99 dataset limits its real-world relevance.

[14] applied shallow and deep auto-encoders with Multiple Kernel Learning (MKL) for DDoS detection in smart grids, achieving high accuracy (97%) and robust feature learning. The model outperformed state-of-the-art methods but requires optimization for larger datasets.

[15] proposed an intrusion detection system using data mining techniques, achieving high accuracy (98.94%) and an AUC of 0.999. However, the study does not address the computational costs or complexity of the approach.

3.Methodology

3.1 Dataset

The dataset used for the evaluation is CICIDS2017, which was due to its extensive range of current attack scenarios, which meet real-world conditions and are widely available and used in the cybersecurity community. Furthermore, it includes results from CICFlowMeter network traffic analysis, with flows categorized by source, timestamp, destination IP addresses, destination ports, protocols, and attack types [16], [5].

Table 1: Database Description

Dataset	Total number of features	BENIGN	DDoS	Total
CICIDS2017	78	97718	128027	225745

3.2 Experimental Evaluation and Metrics

The algorithms were implemented through experimentation in Google Colab using Python code with the CICIDS2017 cyber security dataset. The models are evaluated using the following metrics [18], [19].

Accuracy: The proportion of correctly classified instances.

$$\text{Accuracy} = \frac{TP + TN}{TP + TN + FN + FP} = + \frac{\text{True Positive}}{\text{Total Predicted Positive}} \tag{1}$$

Precision: The ability of the classifier to avoid false positives.

$$\text{Precision} = \frac{TP}{TP + FP} = + \frac{\text{True Positive}}{\text{Total Predicted Positive}} \tag{2}$$

Recall: The ability of the classifier to detect all true positives.

$$\text{Recall} = \frac{TP}{TP + FN} = + \frac{\text{True Positive}}{\text{Total Predicted Positive}} \tag{3}$$

F1-Score: The harmonic mean of precision and recall, providing a balance between the two.

$$\text{F1} - \text{score} = \frac{2 \times (\text{Precision} \times \text{Recall})}{\text{Precision} + \text{Recall}} = + \frac{\text{True Positive}}{\text{Total Predicted Positive}} \tag{4}$$

3.3 Model Training and Testing

The data was split into training (80%) and validation/testing (20%) sets, ensuring a balanced model training and evaluation approach. The models are trained using the training data and evaluated using the testing data.

3.4 Feature Selection

In this critical phase of the machine learning process, the focus was on data preprocessing and feature selection to optimize model performance and predictive accuracy. The process began with identifying and engineering key features that significantly impact resilience, ensuring they effectively capture the relationships within the dataset. Data cleaning was the first step, replacing NaN and infinite values with the mean of the respective columns. Next, features were converted to numerical values using a standard scaler, as shown in equation 5, while labels were encoded, with benign

represented as 0 and DDoS as 1 using equation 6. The dataset was then normalized to a uniform range of [0, 1] to reduce feature discrepancies.
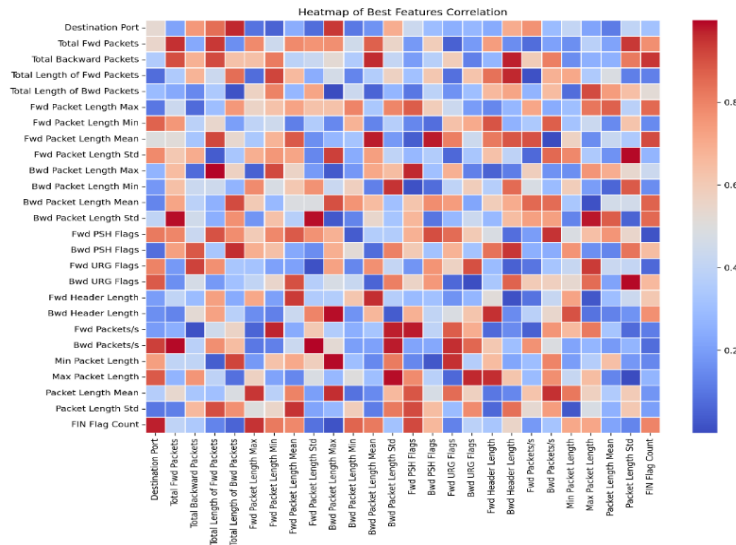

Fig 1: Heatmap of the best features in the Dataset

$$\sigma = \sqrt{\sum_{i=1}^{n}(xi - \mu)^2} \tag{5}$$

$$z = f(x) = \sigma (We^x + b_e) \tag{6}$$

In this paper, ten (10) machine-learning classification algorithms for the detection of DDoS attack on cyber-physical systems were evaluated through experimentation. The algorithms are discussed as follows [20], [21].

    i.   Random Forest: This is an ensemble learning technique that creates multiple decision trees and combines their outputs to enhance accuracy in classification or regression tasks. It is resistant to overfitting and performs well with noisy data.

    ii.   Support Vector Machine (SVM): A powerful classification algorithm that finds the best hyperplane to divide data points into distinct classes. SVMs are effective in high-dimensional spaces and can handle both linear and non-linear data using kernel functions.

    iii.   K-Nearest Neighbors (KNN): An instance-based learning algorithm that classifies data points by considering the majority class among their nearest 'k' neighbors. Although simple and intuitive, KNN can be computationally demanding with large datasets.

    iv.   Decision Trees: These models split data based on feature values, forming a tree-like structure where each node represents a decision rule, and each leaf node represents an outcome. They are easy to understand but can overfit if not appropriately pruned..

    v.   Artificial Neural Networks (ANNs): Inspired by the human brain, these computational models consist of layers of interconnected neurons. ANNs can learn complex patterns in data and are fundamental to deep learning, though they require large amounts of data and significant computational power.

    vi.   Naive Bayes: A probabilistic classifier that applies Bayes' theorem with the assumption of feature independence. Despite this simplification, it performs effectively in tasks like text classification, where the assumption approximately holds.

    vii. Gradient Boosting Machines (GBM): An ensemble method that sequentially builds models, with each new model aimed at correcting the errors of its predecessors. By combining weak learners, typically decision trees, GBMs create a robust predictive model that often yields high accuracy.

viii. Logistic Regression: A linear model for binary classification that estimates the likelihood of a particular outcome based on input features. It is simple, interpretable, and effective when the relationship between variables and the outcome is roughly linear.

ix. Extreme Gradient Boosting (XGBoost): A refined version of gradient boosting that is highly efficient and scalable. XGBoost is known for its speed and accuracy, making it a popular choice in machine learning competitions, especially for large datasets.

x. Recurrent Neural Networks (RNNs): These neural networks are designed for sequential data, with connections that form directed cycles. RNNs are particularly suitable for tasks like time series analysis and natural language processing but may encounter difficulties with long-term dependencies due to issues such as vanishing gradients. The detection framework of the DdoS attack using ten diffirent alogorithm is illustred in Figure 2.
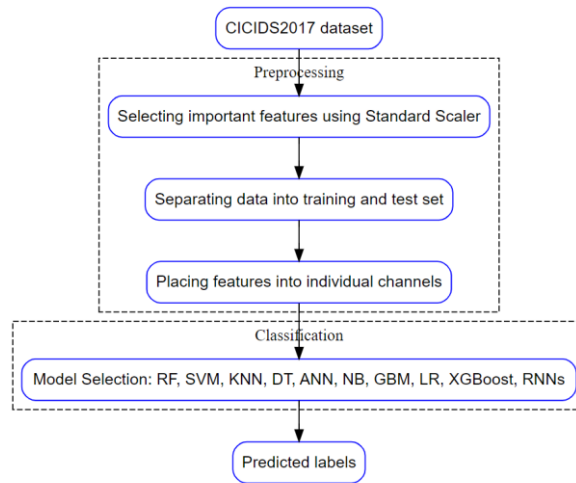
Fig 2: DDoS Detection Framework

4. Results
The performance of each machine learning model is summarized in Table 2

Algorithms	Accuracy (%)	Precision (%)	Recall (%)	F1 score (%)
Random Forest	99.99	99.99	99.99	99.99
SVM	99.86	99.86	99.86	99.86
XGBOOST	100.00	100.00	100.00	100.00
Logistic Regression	99.82	99.82	99.82	99.82
GBM	99.98	99.98	99.98	99.98
Naive Bayes	98.73	98.75	98.73	98.72
Decision Tree	99.99	99.99	99.99	99.99
KNN	99.98	99.98	99.98	99.98
ANN	99.91	99.91	99.91	99.91
RNN	99.86	99.86	99.86	99.86

The results on Table 2 reveal exceptionally high performance across various machine learning algorithms, with accuracy, precision, recall, and F1 scores consistently exceeding 98%. XGBoost stands out with perfect scores of 100% across all metrics, indicating flawless performance, likely due to its advanced boosting techniques that effectively minimize errors. RF, DT, and GBM also show near-perfect results, with scores of 99.99%, underscoring their robustness and effectiveness in handling complex datasets. ANNs, SVM and RNNs exhibit robust and consistent performance, each achieving 99.86% across all metrics, reflecting their capability to model intricate relationships within data KNN and LR also deliver excellent outcomes, with scores of 99.98% and 99.82%, respectively. While Naive Bayes lags slightly behind the others, with scores around 98.73%, it still performs commendably, given its simplicity and the assumption of feature independence. Overall, these results highlight the exceptional capability of each algorithm, with XGBoost, RF, and GBM leading in performance and even the slightly lower-scoring NB remaining a viable option. Figure 3 depicts the comparison of the algorithms. Confusion Matrix(CM) and Receiver Operating Characteristics (ROC) is presented in Figure 4 to 22 respectively.
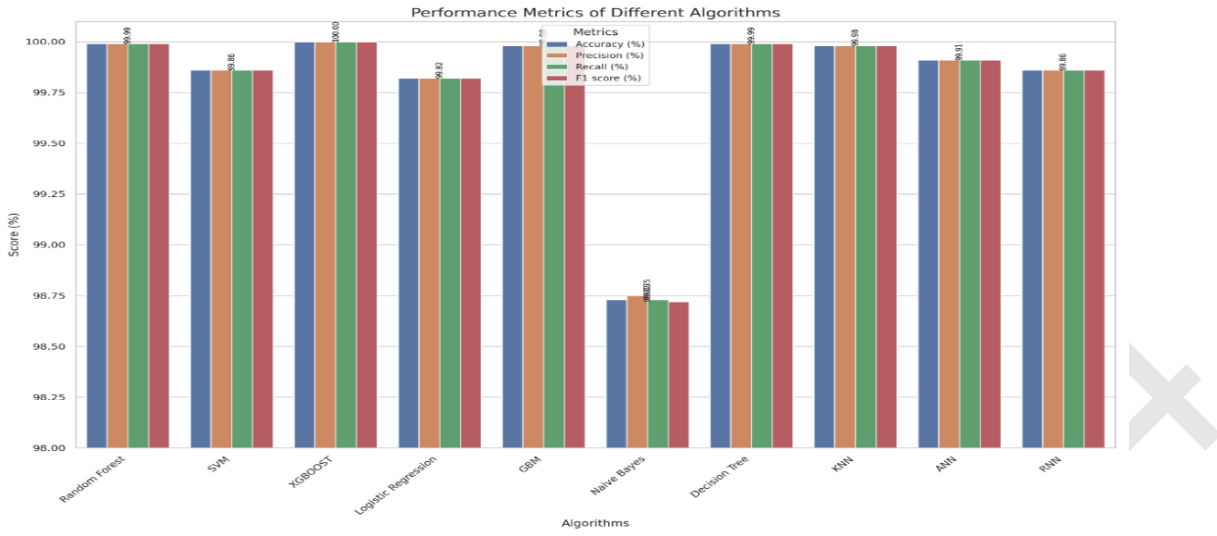
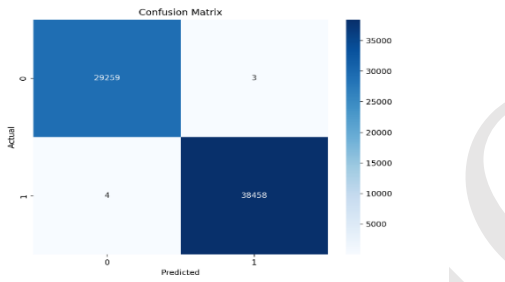Fig 3. Comparisons of the performance of Machine Learning Algorithms
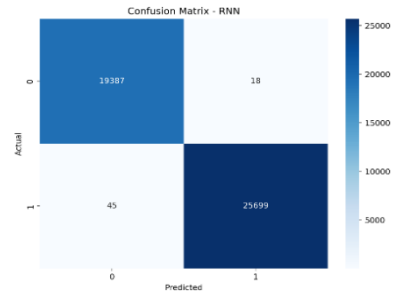

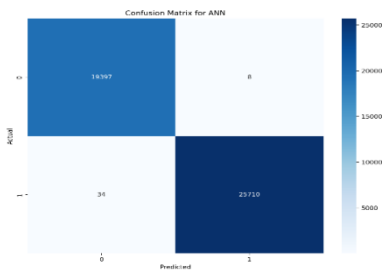**Fig 4: CM of RM Algorithm**

Fig 5: CM of RNN Algorithm

Fig 6: CM of ANN Algorithm
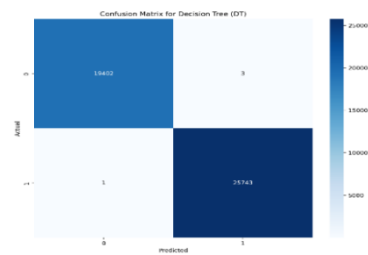
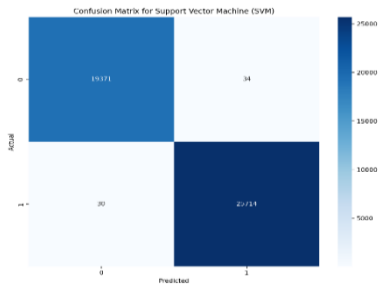**Fig7: CM of DT Algorithm**

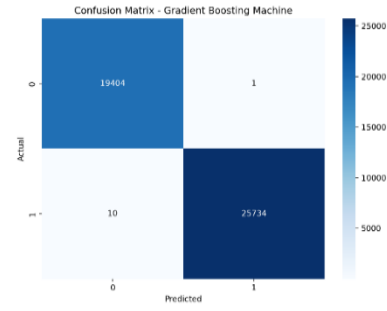**Fig. 8**: **CM of SVM Algorithm**
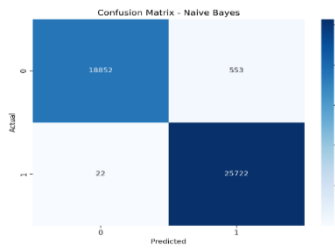

Fig 9: CM of GBM Algorithm

Fig 10: CM of NB Algorithm
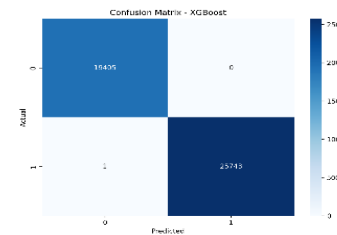
Fig 11: CM of XGB Algorithm
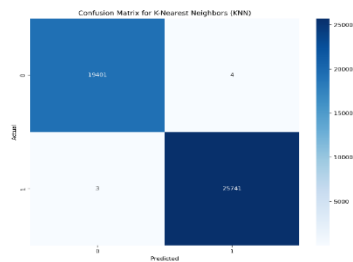
Fig 12: CM of KNN Algorithm
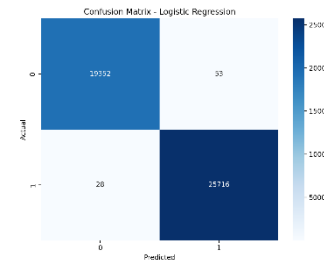
Fig 13: CM of LR Algorithm
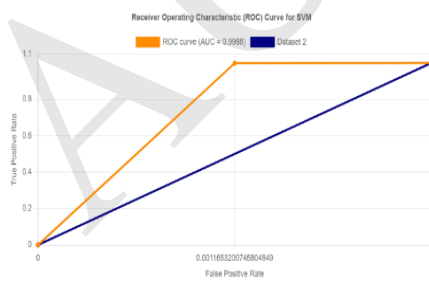
Fig 14: ROC of SVM Algorithm
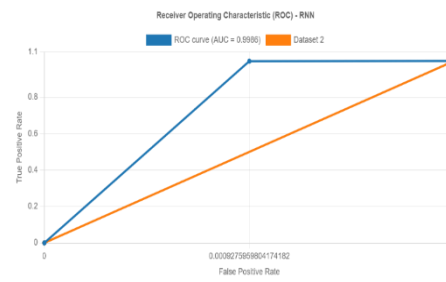
Fig 15: ROC of RNN Algorithm
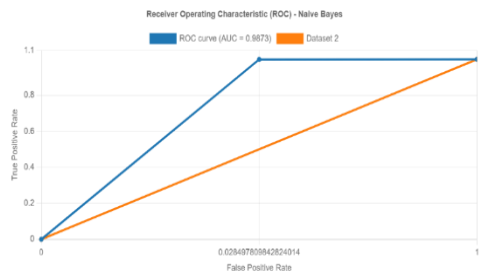
Fig 16: ROC of NB Algorithm
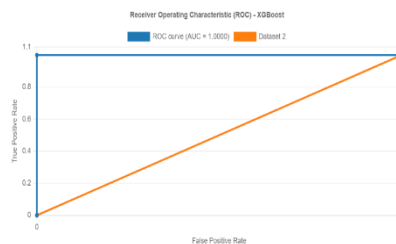
Fig 17: ROC of XGB Algorithm
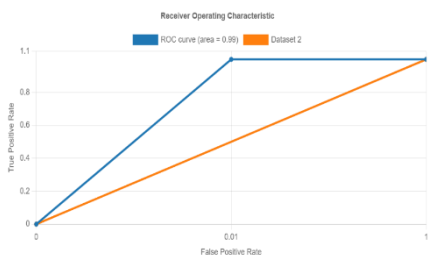
Fig 18: ROC of RF Algorithm
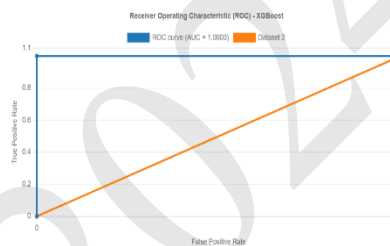
Fig 19: ROC of KNN Algorithm

Fig 20: ROC of DT Algorithm
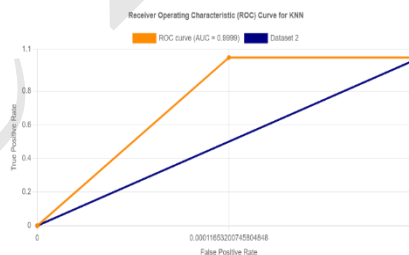
Fig 21: ROC of ANN Algorithm
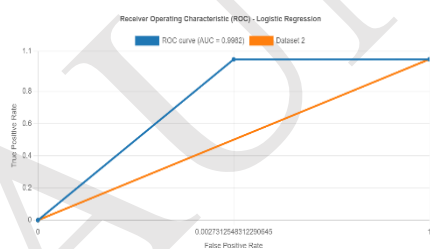
Fig 22: ROC of LR Algorithm
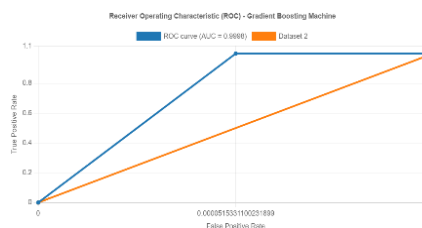
Fig 23: ROC of GBM Algorithm

6. Discussion

This study comprehensively evaluates various machine learning algorithms for detecting DDoS attacks in cyber-physical systems, especially smart grids. Most algorithms performed exceptionally well, with accuracy, precision, recall, and F1 scores exceeding 98%. XGBoost achieved perfect scores across all metrics, demonstrating flawless detection capabilities. Random Forest, Decision Trees, and GBM also showed near-perfect results at 99.99%, highlighting their robustness. SVM, ANNs, and RNNs followed closely with 99.86%, while KNN and Logistic Regression achieved

99.98% and 99.82%, respectively. Although Naive Bayes performed slightly lower at 98.73%, it remained a viable option due to its simplicity. The study emphasizes the effectiveness of advanced algorithms, particularly XGBoost, RF, and GBM, for real-time DDoS detection in smart grids.

7. Conclusion

This study evaluates various machine learning algorithms for detecting DDoS attacks on cyber-physical system in smart grids, showing that most achieved over 99% accuracy, precision, recall, and F1-score. XGBoost was the top performer with flawless detection, while Random Forest, Decision Trees, and Gradient Boosting Machines also demonstrated near-perfect results. Simpler models like Naive Bayes performed slightly lower but remained effective in specific contexts. The study underscores the crucial role of machine learning in ensuring the security of cyber-physical systems. It suggests future research focus on integrating these models into real-time detection systems for enhanced practical application.

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Implementing Advanced Security Measures in Asterisk-Driven VoIP Networks

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Abstract - Voice over Internet Protocol (VoIP) is a rapidly advancing technology that facilitates the transmission of voice and audio signals over the Internet or an IP-based network in real-time. This technology has seen a significant rise in demand due to its advantages over traditional circuit-switched telephony, including lower call rates, reduced operational costs, easier management, and enhanced call features. However, the growth in VoIP usage has also increased the potential for various security threats and attacks, jeopardizing the privacy, confidentiality, and integrity of transmitted data. This paper presents the design of an Asterisk-based VoIP system and the implementation of a comprehensive security solution across the VoIP network. The study involves an in-depth analysis of VoIP technology, identifying its vulnerabilities and addressing potential threats. A security framework is proposed and implemented to safeguard the VoIP network. The designed system and security solutions are rigorously tested and evaluated to ensure robustness and effectiveness. The findings highlight critical security measures necessary for protecting VoIP infrastructures and provide a framework for future research and development in securing VoIP networks.

Keywords: Asterisk, Codec, Cybersecurity, IPsec, Malware, Network Security, Phishing, Telecoms, Threats, Telephony, VoIP

1   INTRODUCTION

Voice over Internet Protocol (VoIP) revolutionized telecommunications by enabling voice communication over networks, beginning with VocalTec's first internet softphone in 1995 [1]. Early VoIP faced challenges due to limited bandwidth and poor modem technology [2]. However, broadband improvements enhanced VoIP's Quality of Service (QoS), leading to its widespread adoption and potential to replace traditional PSTN systems [3]. VoIP uses internet broadband to transmit voice over IP networks, reducing communication costs and enabling advanced communication applications like web and video conferencing [4]-[7].

VoIP offers cost savings by avoiding the high tolls of conventional telecommunication lines, and supports rich media services such as voice and video calls [8]-[10]. Its open standards allow integration with backend systems and features like user attributes can move with users globally. However, VoIP's complex service architecture makes designing and troubleshooting challenging, and it depends on power supply, making it vulnerable to outages, unlike PSTN systems with backup power [11]. Security concerns are also significant as VoIP services are more vulnerable compared to PSTN systems. VoIP networks perform more tasks than PSTN, including gateway functions, without requiring all the equipment used in PSTN networks [12].

2   VOIP – Components, Codec, security threats and attacks

The network Component. Includes routers, switches, firewalls, cabling, and PBX [12]. These components must detect, prioritise, and allow VoIP traffic to reach its destination [13] reducing latency. The IP PBX switches calls between VoIP and PSTN users, making it vital to the network [14].

Gateways convert voice calls or signals between packet switched and circuit switched networks in real time [15] and divides gateways into three categories namely:

Media gateways which carries voice signals over IP networks. It detects calls, originates them, and converts analogue to digital voice. **Media gateway controllers** that signal which control, and coordinate the media gateway. [13] Explains that this component's duties include host searching, resource management, phone number translation, and signal functionality. **End-user equipment**; allows network endpoint connectivity. VoIP, soft, and classic phones with audio and video conferencing, instant messaging, and surveillance features may be used by end users [16].

VoIP phones use TCP/IP to communicate with the parent IP network and can be configured manually or using DHCP [17]. Soft phone software can be installed on a PC and used to make calls online [43]

VoIP protocols and codecs – [12] VoIP protocols are categorized into two main categories namely;

Signalling protocols. [18] Defines signalling protocols as those responsible for call setup, monitoring, teardown, and setup negotiation, management, and modifications. These protocols ensure user location, negotiate call sessions, and manage calls. [19] Identified SIP and H.323 as the most commonly used signalling protocols in the VoIP market.

Session Initiation Protocol (SIP) is an application layer signalling protocol primarily used for establishing, modifying, and terminating multimedia sessions between endpoints [20] and [21]. The design philosophy and architecture of the system can be considered to have been derived from the hypertext transfer protocol (HTTP) and the simple mail transfer protocol (SMTP), hence guaranteeing its simplicity [22].

H.323 - This protocol establishes a decentralised structure for developing multimedia applications, such as VoIP [44] and facilitates communication between different devices. It is largely utilised for ISDN video conferencing systems and toll pass VoIP applications, as stated by [23]. [24], categorise the H.323 network into the following fundamental components: Endpoints, Gatekeepers that offer signalling services, Multipoint control units that guarantee the accessibility of conferencing services and Gateways. [25].

Media transport protocols. [12] states that media transport protocol controls voice sample encoding, decoding, digitization, and ordering for real-time communication. Media transport protocols, such as real-time and real-time control protocols will be examined here.
The real time protocol is designed to transmit real-time audio or video data over a user data protocol (UDP) [26] however it does not guarantee real-time delivery [18] RTP offers features such as identifying payload type, sequence number, monitoring data transmission, and time sharing. The Real Time Control protocol (RTCP) provides feedback on the quality of service of transmitted data disseminated using real-time protocols. RTCP monitors VoIP issues such latency, delays, and jitters and communicates control information [27].
[28] Defines CODEC as an algorithm that is used to encode and decode voice streams across a network. Encoding is done to enable the voice signal which is Analog to be digitalized and transmitted across the network.

VoIP Codec - At the receiver's end, the signal needs to be decoded, hence its conversion back to Analog stream. The digitization of voice streams is categorized into two processes: sampling and quantization [29]. Common VoIP CODEC used include G.711, G.722, G723.1, G.726 and G.729 [30]

VoIP security threats, attacks, and vulnerabilities - Security of users can be analysed by examining threats, attacks, and vulnerabilities in VoIP networks. [31] And [32] categorized VoIP threats into those against availability, confidentiality, and integrity. Threats against availability disrupt VoIP services, such as denial of service [30]. Examples include call flooding, call hijacking, spoofed messages, and server impersonation [33]

Threats against confidentiality involve stealing caller identities, such as eavesdropping, impersonation, and call pattern tracking [32] and [34] Threats against integrity alter intercepted messages, like call rerouting and media alteration [35] and [11].

Threats against social context involve misrepresenting identities to convey false information [11]. Examples include phishing and spam [35].

Best practices for VoIP security and deployment - A comprehensive security strategy is essential to counter rising VoIP threats. Key practices include:
Network Address Translation (NAT): NAT converts private IP addresses to public ones, concealing internal IPs and adding security [36]. Research by [37] and [13] shows NAT enhances security and addresses IP limitations.

Firewall Deployment: Firewalls, positioned at network boundaries, filter traffic and protect against intruders [13] and [34] Proper deployment prevents unauthorized access [32]. [38] Categorizes firewalls into packet filtering, application-level gateway, and circuit-level gateway.

Virtual Private Network (VPN): VPNs secure data transmission over public networks through encryption [39] and [36] VPN types include site-to-site and remote access [40]. IPSec VPN and SSL VPN provide high levels of security .In conclusion, NAT, firewalls, and VPNs are essential for securing VoIP networks.

Based on the review, it has been narrowed down the Network address translation deployment, firewall deployment and Virtual private network.

3   METHODOLOGY

The methodology adopted is based on outlining the technical requirements for carrying out the design and implementation of the network design, the VoIP dial plan and numbering system was also designed, VoIP design methods and the choice of the design tools to be made use of was analysed. In addition, secondary data sources such as research papers, publications, and internet and journal newspapers was used for descriptive sections of the research. Several factors were taken into consideration from the in depth literature review before the implementation design methods was adopted. Factors ranging from the Quality of service issues in Voice over IP networks, security considerations and concerns was analysed in depth and critically.

4   REQUIREMENTS FOR THE VOIP TELEPHONY NETWORK DESIGN.

The requirements of the based design aspect range from Design of an asterisk VoIP based system, Design and integration of a voicemail service system in the Asterisk PBX, Design of a suitable dial plan for the two network site locations and Design and integration of a security solution across the network

Branches with their offices and number of extensions needed - The list of offices and departments in Lagos and Abuja is crucial for designing the dial plan, influencing the choice of the numbering system. During implementation, soft phones were chosen over hard phones due to the limited availability of the latter.

Design of the dial plan and numbering system – [41] stated that dial plan is very important since it handles the inbound and outbound calls in the network through a set of instructions that asterisk have to follow. A four digit dial plan is made use of in the implementation of the project and numbering system. The reason behind this is to give a greater room for expansion of the organisation should the need arise.

Table 1.0: Dial plan table

Department	Abuja Extension Numbers	Lagos Extension Number
Administration	1101 - 1199	2101 - 2199
Accounting	1201 - 1299	2201 - 2299
IT/Engineering	1301 - 1399	2301 - 2399
Sales	1401 - 1499	2401 - 2499
Legal	1501 - 1599	2501 - 2599

Methods and tools used for the design
Asterisk IP PBX; The choice of the asterisk was made since it's an open source, it will be cost effective to deploy, easy to manage, easy access to support as against propriety software, ease of management, little or no complexity in the configuration of the asterisk PBX to include addition features such as auto attendant, voice mail, call conferencing among others..

Session initiation protocol (SIP); this protocol was chosen for its ease of implementation as opposed to other protocols that could also be used for instance the H.323 protocol [34], [21].

IPsec VPN; this offers a strong form of security in the form of encryption, encapsulation of packets and tunnelling during the transmission of data across the network [39]. comparison was made between the IPsec VPN, Secure socket layer (SSL) VPN, firewall deployment and it the adoption of the IPsec VPN was done since its more advantageous and stronger in comparison to the other security methodologies. This is also supported by research done by reputable authors like [42].

Four Digit Dial plan Numbering system; There is room for growth and also because of its scalability as opposed to the three digit numbering system. [43].

Voice mail design; this configuration of the voicemail is achieved by inserting the appropriate settings in the Voicemail.conf file present in the etc/asterisk folder on the asterisk server.

5   SECURITY IMPLEMENTATION ACROSS THE ASTERISK-BASED VOIP NETWORK.

There is the strong need to ensure the security of the VoIP network against unauthorized entry by malicious users. The adoption of the IPsec VPN as against the other security solutions for implementation is based on the numerous advantages it has over others, some of which include but not restricted to;

Encryption and tunnelling allow secure voice packet transmission over the network, enhancing data security and confidentiality. It is also more scalable, flexible and reliable as opposed to the other security solutions. It is cheaper and easier to deploy as opposed to other security solutions and its maintenance and running cost is low
The IPsec site-to-site VPN was chosen for this project due to its ability to maintain confidentiality, site to site security and anonymity. AES encryption was selected for the project. IPsec VPN ensures safe data transit between crypto-enabled peers hence ensuring a secure data transfer between the different peers. IPsec includes two protocols for better security: the Authentication header and Encapsulation Security Protocol (ESP) and the Internet Security Association and Key Management (ISAKMP). To ensure the proper security of the transmitted data, the use of a symmetrical encryption algorithm and the internet key exchange mechanism for safe exchange of keys is recommended.

This security method prevents packet eavesdropping and alteration. Network administrators can modify Hashed Message Authentication codes to enhance setting strength. The IPSec VPN ensures sender-receiver authentication, ESP protocols assure data confidentiality, and AH protocols maintain integrity.

Tools used for design implementation

The design of the VoIP telephony solution was done making use of both soft phones and hard phones to ensure full compatibility of both the soft phones and hard phones with the project design.

Fedora operating system - which is the plat form in which the asterisk PBX will be run on. Session initiation protocol (SIP) - this protocol was specifically adopted for the design since most products in the market as of today as SIP compliant as against the other protocols especially IAX2.

Asterisk which is an open source - this software transform an ordinary computer into a communication server. **Astra IP Hard phones** (9133i model) - used for the calls between the two servers and also for the configuration of the Voicemail and auto attendant system. X-lite 4 soft phones - to test for its compatibility with the design. IPsec site-to-site VPN; this was also implemented across the VoIP telephony network. Four digit dial plan; this was used in the design of the dial plan numbering system for the asterisk PBX. This was chosen to give room for the company's expansion or growth; hence accommodating more extensions. Cisco Routers 2800 series, Cisco 2950 switches and PC systems
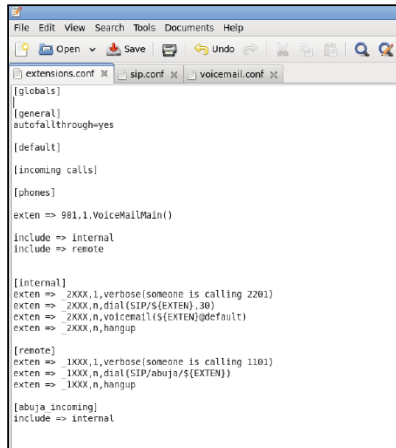
IP addressing scheme -The IP addressing scheme used for the design of the network is a Class C addressing.

Table 2.0: shows the IP addressing scheme for the project design

SN	Description	Abuja Router	Lagos Router
1	Serial Interface IP address S0/0/0	192.168.1.1/24	192.168.1.2/24
2	Fast Ethernet IP address F0/0	192.168.2.1/24	192.168.3.1/24
3	1st extension IP address	192.168.2.2/24	192.168.3.2/24
4	Network IP address	192.168.2.0/24	192.168.3.0/24
5	IP PBX IP address	192.168.2.3/24	192.168.3.3/24
6	1st host system address	192.168.2.4/24	192.168.3.4/24

Asterisk and VoIP phone configurations.

Extension.conf: it contains the dial plan which defines and handles how calls come in, go out and are also routed. The behaviour of the PBX connection can be configured in the file.

Figure 1.0: Extension.conf file

The Extension.conf file is usually located in the etc/asterisk directory as the case may be. Dial plan can be categorized into three main concepts namely

Contexts. The main purpose of the contexts in an Extension.conf file is to keep the different parts of the dial plan from interacting with one another.
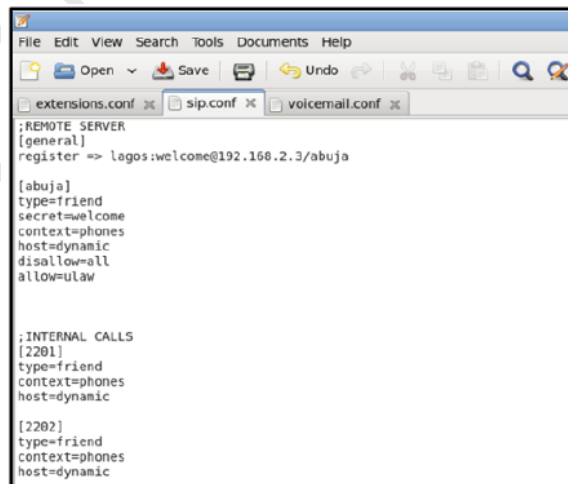
The context also provides some level of security by either permitting or denying a caller's access to certain features. All the instructions placed after the [general] context are part of the context unless another context is specified. The autofallthrough=yes tells the asterisk to continue running the configurations even when the extension doesn't have anything to do.

Extensions. An extension comprises of three components: The name, priority and application. These components are separated by commas as shown in an example below; exten => name,priority,application()

Priority. This can be defined as multiple steps in an extension which are normally executed sequentially, for example; *exten => 123,1,answer()* exten => 123,1,hangup(). First priority 1 is to answer the call followed by priority 2 to hang up the call

Application. This is defined as the work horses of the overall asterisk dial plan each performing its specific function, for example answering a call, dialling a number, playing a sound or hanging up a call. Some of the applications include answer(), hangup().

SIP.conf. The authentication of the users and end points including SIP phones is configured in the SIP.conf file. The file is usually used for the determination of calls to be answered or rejected by the user by the asterisk PBX.

Figure 2.0: SIP.conf configuration file

The explanation of the SIP.conf file is detailed below
[abuja]; the content of the context is then name of the SIP device which could also be the extension number
Type = friend; since asterisk PBX is designed for both calls to be placed to the phones and received as well, the type is defined as friend. The other options that can be set under type are;

User; which is mainly for calls leaving the dial plan which is usually through the Dial () application. The type friend is preferred since it defines both the user and the peer.

Host; this option is used to define the users or clients that exist on the network. The asterisk PBX receives a REGISTER packet telling it which IP address the SIP peer is using.

Secret; this sets the password that has to be entered before a client is added to the network. This option also secures an untrusted network by forcing the use of password (secret=password).

Context = phones; this defines the dial context for the user which in this case is phone

Voicemail.conf. This file contains settings used for configuring and customizing Voicemail to meet specific requirements and needs. The Voicemail.conf file is divided into three sections as shown below;

[general] which contains the global configurations of the Voicemail.conf file. [zone messages]; this section deals with corresponding the different time zones together with the local time zones. This is due to the time difference. Context defined

The syntax for defining a mail box is mailbox => password, name,[email,pager_email [options]]] where the mail box number corresponds to the extension number associated with it. Password is that which is assigned to the mail box by the user to have access to the mail box which is updated by the asterisk PBX in Voicemail.conf

Starting and shutting down an asterisk server - Asterisk is usually run on Fedora or Linux operating system as the case may be and depending on choice. The Extension.conf, SIP.conf and Voicemail.conf configuration files are placed into the etc/asterisk folder. The asterisk server is initiated by inputting this command in the command line interface on the fedora server asterisk – vvvvvvvvvvvvvvvc which automatically registers the clients and also establish connection.

It can be stopped should the need arise by entering the command stop core gracefully in the command line interface. The registration of the SIP peers is done after successful registration and start up process is completed.
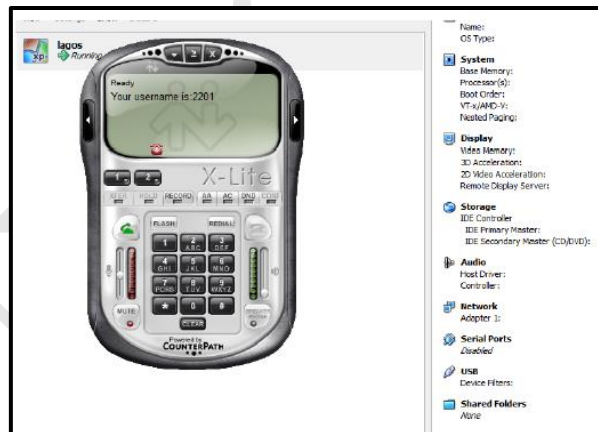
Figure 3.0: registered SIP phone

The Call Process

This is done by entering in the specified parameters such as the IP address of the server, port number, the username and the extension. The configuration of the phone device is shown below in figure.
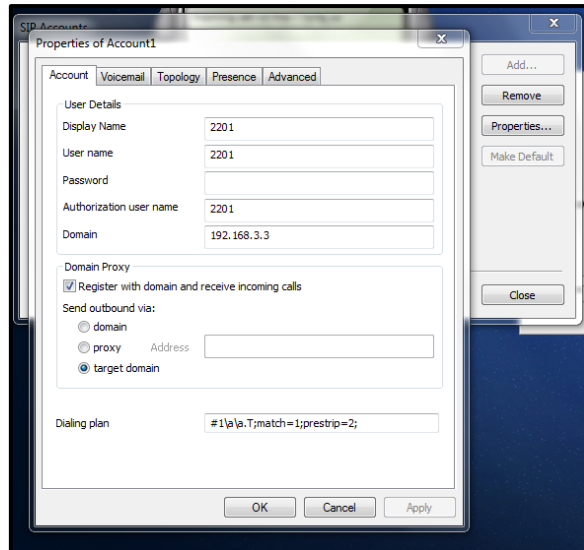
Figure 4.0: configured X-Lite 4 soft phone

Security implementation (e.g., IPSec site-to-site security, IPSec VPN).

IPsec site-to-site VPN solution will be implemented across Abuja Lagos branches of the asterisk VoIP based design. The IPsec VPN combines both tunnelling, encapsulation and encryption of the packet transmitted across the network hence ensuring a secured network and also confidentiality of information across the network.

The stages are broken into Initiation of the interesting traffic stage, Internet key Exchange (IKE) phase 1, Internet key Exchange (IKE) phase 2, Transfer of data and Termination of IPSec Tunnel.

Implementation of IPsec VPN in the VoIP telephony network

Initiation of interesting traffic; the interesting traffic here is between the Abuja server and the Lagos server branches respectively. The access list is set up as follows;

Access-list 101 permit ip 192.168.2.0 0.0.0.255 192.168.3.0 0 0.0.0.255
Access-list 101 permit ip 192.168.3.0 0.0.0.255 192.168.2.0 0 0.0.0.255

IKE Phase 1 stage; in this stage the authentication of the IPsec peers by the IKE is carried out. It also carries out security association negotiations and also the creation of a secure channel for the association of the IPsec security. **The commands used for achieving the phase 1 are shown below with explanation of each command line.**

Crypto isakmp enable; enables the ISAKMP protocol
Crypto isakmp policy 1; starts setting up our security associations.
Encryption 3des; includes the des encryption
Authentication pre-share; includes the authentication type and hashing algorithms
Group 1; specifies the group
Lifetime 86400; specifies the time before re-authentication starts
Exit; exits the mode it's currently in
Crypto isakmp identity address; sets how the peer machine is recognized
Crypto isakmp key washima address 192.168.1.2; this command sets the key and the peer address

IKE Phase 2 stage; in this stage, the negotiation of the security association parameters of the IPSec is done and are set in the IPSec security peers. This ensures the protection of the transmitted data between the two servers. The commands used in this stage are shown below;

Crypto ipsec transform-set secured esp-md5-hmac; encrypts the IPSec tunnel using the des and MD5 hashing algorithm.
Mode tunnel; takes us into the tunnel mode
Crypto map abuja 1 ipsec-isakmp; IPSec association policy itself
Set peer 192.168.1.2; sets the peer IP address
Set transform-set SECURITY; used to secure channel

Set security association lifetime seconds 86400; time before re-authentication restarts
Match address 101; tells the IPSec tunnel about interesting traffic
Exit; leave the present mode
Data transfer; exchange of data is done between the peers and the keys are saved in the security association file.
The termination of the IPsec tunnel is done either by completely deleting or by timing out process.

6   TESTING

Testing of the VoIP telephony network - The telephony network is tested by ensuring that servers can both dial and receive call among them as shown in the figures below. This can be achieved by using the ping command to test for connectivity between the servers and also dialling the different extension numbers.

Ping command; this test for connectivity between two points by sending of packets from the source to the destination. 100% delivery signifies success otherwise unsuccessful.

Show IP route command; this command shows the routing table of the router, showing a list of all networks the router can establish connection with.

Testing the IPsec security - The testing of the security solution is to ensure that the IPsec security has been correctly deployed and is fully functional.

The following commands was issued on the router to ensure the network was properly configured with IPsec site to site VPN and is fully functional and operational.

Show crypto IPSec sa; this command is used to show the security association built between the peers on the network. This also shows the tunnel that has been built between the 192.168.1.2 source point and its peer 192.168.1.1. It also shows the encapsulation security payload both at the inbound and outbound.

Show crypto engine connections active; this displays the active security associations on the router along with the number of encrypted and decrypted packets for each security association.

```
lagos#show crypto engine connections active
Crypto Engine Connections

  ID Interface  Type  Algorithm          Encrypt  Decrypt IP-Address
1001 Se0/0/0    IKE   SHA+AES                  0        0 192.168.1.2
2001 Se0/0/0    IPsec DES+MD5                  0       41 192.168.1.2
2002 Se0/0/0    IPsec DES+MD5                 41        0 192.168.1.2
```
Figure 5.0: show crypto engine connections active

Show crypto IPsec transform-set; this delivers a transform set and shows the transform combination in use.

```
lagos#show crypto ipsec transform-set
Transform set SECURITY: á esp-des esp-md5-hmac  ú
    will negotiate = á Tunnel,  ú,
```
Figure 6.0: show crypto ipsec transform set output

Show crypto isakmp key; this command displays the preshared key. The figure 9 shows the output.

```
lagos#show crypto isakmp key
Keyring       Hostname/Address                        Preshared Key

default       192.168.1.1                             washima
lagos#
```
Figure 7.0: show crypto isakmp key output

Show crypto isakmp peers; this shows the local IP address and the peer's IP address.

```
lagos#show crypto isakmp peers
Peer: 192.168.1.1 Port:  500 Local: 192.168.1.2
  Phase1 id: 192.168.1.1
lagos#
```
Figure 8.0: show crypto isakmp peers output

Show crypto isakmp policy; this displays the parameter for each IKE policy.

```
lagos#show crypto isakmp policy

Global IKE policy
Protection suite of priority 1
        encryption algorithm:   AES - Advanced Encryption Standard (128 bit keys).
        hash algorithm:         Secure Hash Standard
        authentication method:  Pre-Shared Key
        Diffie-Hellman group:   #2 (1024 bit)
        lifetime:               86400 seconds, no volume limit
Default protection suite
        encryption algorithm:   DES - Data Encryption Standard (56 bit keys).
        hash algorithm:         Secure Hash Standard
        authentication method:  Rivest-Shamir-Adleman Signature
        Diffie-Hellman group:   #1 (768 bit)
        lifetime:               86400 seconds, no volume limit
lagos#
```
Figure 9.0: show crypto isakmp policy output

Show crypto map; this shows the crypto map configurations.

Figure 10.0: show crypto map output

When the IPsec security was turned off between the branches by using the **no crypto map** command. The Wireshark was able to capture packets. When the IPsec security was turned on the Wireshark could not capture the data since all the information became hidden and fully encrypted by its replacement with the encapsulation security payload (ESP).

7   EVALUATION - Weaknesses, problems and setbacks in the Project Design

Weakness in Asterisk Software: As an open source platform, Asterisk lacks the accountability and guaranteed maintenance, repairs, and upgrades provided by proprietary solutions like Cisco. This risk suggests a preference for proprietary options, though configuration backups can be stored externally.

Effect of Security Solution Deployment: The IPsec VPN uses a shared key for authentication, which compromises security if breached, undermining the tunnelling purpose. Additionally, bandwidth utilization and quality of service issues can degrade overall network performance during calls.

Numbering System Used: The four-digit numbering system may become difficult to manage as departments grow, leading to potential number wastage or shortages.

8   CONCLUSION

The design of the VoIP-based network began with in-depth research and a critical comparison to the existing Public Switch Telephone Network. The advantages of VoIP were discussed with references to various published papers. A comparison of different VoIP protocols led to the recommendation of the SIP protocol for the asterisk VoIP network, supported by research from [21] and [24]. A critical analysis of VoIP attacks, such as man-in-the-middle, call flooding, and spoofing, was conducted. Security methodologies were compared, leading to the recommendation of IPsec site-to-site VPN for strong protection. The design included a dial plan and numbering system based on required extensions. The implementation phase involved configuring VDI images, Oracle VirtualBox, and critical server files (Extension.conf, SIP.conf, and Voicemail.conf). The network was tested through inter-branch calls and IPsec VPN functionality, confirming full security and operational status.

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UNDERSTANDING THE EFFECTS OF SOME ACADEMIC FACTORS ON THE STUDENT ACADEMIC PERFORMANCE IN INFORMATION SYSTEMS PROGRAMME: A CASE STUDY OF AMERICAN UNIVERSITY OF NIGERIA

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Abstract. Many studies have been carried out to investigate the factors affecting college students' academic performance. The main purpose of this study is to gain an understanding on the academic factors affecting the academic performance of information systems (IS) students in Nigeria. The success rate of IS student in Nigeria universities is low compared to universities outside Nigeria. The number of universities that offer IS as a major are few, a developing country like Nigeria is yet to understand the importance of IS. Therefore, people pay little or no attention to that field of study, which creates countless factors that could affect the IS. The survey methodology was used to study the academic factors affecting the success of IS students in Nigeria universities. A structured survey questionnaire was used to generate data. Statistical Package for the Social Sciences (SPSS) was used as a tool for the data analysis. The results of this study offer an important insight into the academic factors that affect the academic performance of students in the department of IS at undergraduate level.

Keywords: Information systems, Academic factors, Students performance.

1   Introduction

Student are the most important assets of schools and universities, as they have no worth without students. The social and economic development of a country is linked with the amount of quality graduates its universities produce. The students' academic achievement shapes them into graduates who would become great leaders, making them responsible for the country's economic and social development [1].

Educational institutions are highly interested in recruiting students who are most likely to succeed on their academic program. Universities have the professional and ethical responsibility to produce well educated, knowledgably and skilled IS professionals who should be competent enough to adapt to the dynamic growing market. To achieve this goal, university require efficient and reliable indicators of academic success that ensures they enroll candidate with the potential to succeed academically and become skillful IS professionals. There is proof that certain academic factors such as Academic Interaction, learning skills, study habit, school environment, availability of teaching materials, availability of learning materials, and faculty assessment could predict the success of IS students on their academic programs [2].

Quite a number of research's has been carried out to identify the predictors of academic performance of students in various professional programs. However, the majority of such studies were carried out in developed countries, limited research has been carried out to identify the predictors of success of IS students in Nigeria. IS education in Nigeria is provided through a four-year Bachelor Degree programme. At the end of each year student transition in a different stage of learning experience, every examination written in the academic year determines their ability to successfully complete the major. Student who met the requirement to successfully complete the major after four-years are awarded with a Bachelor Degree in IS [2].

This study would be conducted to understand how certain academic factors can affect the academic performance of IS student in a four-year bachelor degree programme in Nigeria Universities. IS which being a major that prepares student to be successful IS professionals, through a program that combines technical computing knowledge, skills and techniques with relevant business knowledge. At the end of the program student also get to build management skills and they are suited to take on roles in management, business systems analysis, IT consulting, data analytics and IT implementation. In Nigeria, as of this year 2022, there is a total of nine university offering IS as a major [3].

The fourth Sustainable Development Goal (SDG) of the United Nations is to "provide inclusive and equitable quality education and promote opportunities for lifelong learning for all." [4]. Previous studies have proof that quality education

is very complex, one of its key components is academic performance of students. Several studies have been carried out to assess the academic performance of students and the factors affecting students' performance. The academic performance of student is dependent on a combination of many variables, like the academic factors. Understanding what are the academic factors affecting the academic performance of IS student in Nigeria and associating how it affects IS Students was what this research seeks to achieve. Therefore, we pose the following research questions:

- RQ1: What is the association between academic factors and academic performance of IS students in Nigeria universities?
- RQ2: Which academic factors can predict the academic performance of IS students in Nigeria universities?

The rest of this paper is organized as follows: Sect. 2 consist of the literature review and conceptual framework. Section 3 discusses the methodology. Section 4 presents the research findings and discussion. Section 5 presents the conclusion.

2   Literature Review

2.1   Definition of Key Concepts

The main concept of this study is the key variable academic performance, this is because academic performance generally refers to how well a student is excelling and achieving their short or long-time educational goals; and it determines the failure or success of an academic institution [5].

Academic performance has been defined by so many authors from different point of views. According to [13], academic performance is the knowledge gain by students over a specific period of time, which is mark by the instructor. This authors also said that these are goals set to achieve by students are measured using assessment and examination results. [14] also said the academic performance is the measurable and observable behavior of student towards academic related activities over a certain period of time. It also consists of scores obtained by a student in assessments such as class exercise, assignment, presentation, mid semester and end of the semester examination.

The above definition given by these authors, shows that the definition of academic performance in its simplest meaning is based on measurable outcomes such as class exercise, assignment, presentation, mid semester and end of the semester examination. Based on this, the operational definition of academic performance in this study, is the result obtained by IS student in Nigeria universities by the end of a semester.

2.2   The Academic Factors Contributing to Academic Performance

Numerous research has been carried out in various countries to determine the factors that influence students' academic performance at various levels. In Nigeria, [15] found out that insufficient facilities including classrooms, labs, electricity, water supply, playing fields, staff offices, and hostels have an impact on students' academic performance in southwest Nigeria. A study conducted by [16] in Benin revealed that Students who have a lot of work to do and assignment become stressed, which can prevent them from allocating enough time for other study-related activities. Academic stress has a negative effect on students' academic performance as well as their physical and psychological health. Additionally, [14] found that class size has a significant effective on the motivation students feel towards attending classes and towards their studies. The study also revealed that student may easily get distracted during class time as large classes are often noisy and rowdy which leads to discouragement. Students may also lose their attention from what the teacher is trying to educated them on about because of their far distances from the board, which makes the teachers voice less audible and the writings on the board on unclear. Also student of Sohar university are greatly influenced by personal factors which have greatly impact to their academic performance. Students also perceived that institutional related factors pose a great effective to their academic performance as they prefer quiet and comfortable university environment. Students also believe that teachers using a variety of teaching skills have a more positive effect to their academic performance. This is because different student performs well in their academics when suitable teaching skills is used to teach them.

Moreover, students are more interested in specializations that would be "interesting", provide them with "job security", and "pay them well". Some studies discovered that the main reasons students do not choose the IS specialization are that they are 'not interested', 'find another specialization more interesting'; or feel that 'IS is too difficult. Furthermore, the study also found out that students who specialize in IS were motivated by a general "interest in technology", "success in the area (self-efficacy)", "job prospects", and "potential income" [6].

The discussion above proves that academic performance of students in general and IS students is influenced by a combination of academic factors which includes: Academic Interaction, learning skills, study habit, school environment,

availability of teaching, availability of learning materials, and faculty assessment. There is a research gap in terms of understanding how certain academic factors affect the IS students' performance. Several conducted studies on student academic performance focus on general academic factors rather that the context of IS.

2.3 Conceptual Framework

For this research we would be considering three important factors that could have the most effect on IS students enrolled in the American university of Nigeria. These variables are also the independent factors of the research, they include, class assessment, student study habits and faculty assessment. All the above-mentioned independent variables can possibly affect the dependent variable which is the academic performance (CGPA) of IS students. Authors of previous research have used these factors to explain how they affect the academic performance of student in various fields of study but first a brief explanation of what these factors imply would be useful.

Independent variables
Class assessment: this refers to the methods used to evaluate the learning progress and improvement of a student in a particular class. It may include different forms of assessment such as quizzes, project, presentations, assignments, class attendance and examinations.

Faculty Assessment: it refers to the evaluation of an instructor's teaching effectiveness and his/her cognitive quality. It may consist of factors such as communication skills, attitude towards duties, knowledge on the course or subject, accessibility or support given to students.

Student study habits: consists of a student behavior, dedication, strategies or approaches student use in engaging with their academic materials. This may include activities such as regular studying, proper time management, attending study sessions or tutorial sessions, note taking and active class participation.

Dependent variable

Academic performance: is the total achievement of a student in their educational pursuit or the extent as to which a student has successfully met the learning standards set by the educational institution. Most times it is measured using grades, grade point average (GPA), or other methods that indicates mastery of the subject matter.

2.4 Proposed relationship between dependent and independent variables

Class Assessment and Academic Performance

The hypothesis is that class assessment has an effect on academic performance, a well aligned assessment which has accurately measure all learning outcomes should positively influence academic performance of IS students. [17] conducted a study which investigated the relationship between classroom assessment methods and the academic performance of medical student. The study used class assessment to examine the impact of different assessment types (multiple choice question and short answer question) on student overall performance [17]. I decided to use the factor class assessment in this research to examine how it impacts academic performance of IS students because it has been used by previous study. It also makes up the sum of learning and determines the grade a student may be scored by at the end of the semester; the grade can either affect the CGPA or GPA positively or negatively.

Faculty Assessment and Academic Performance. The quality of instructors and their ability to effectively engage with student and provide them with support can affect their academic performance. A positive faculty assessment that measures all learning outcomes should correspond with a higher academic performance. [7] Conducted a study which investigated the relationship between faculty assessment and student academic achievement in higher education institutions in Iraq. This study used faculty assessment/faculty evaluation to examine how the factor affects student academic performance in higher institutions [7]. I decided to use the factor faculty assessment in this research to examine how it impacts academic performance of IS students because it has been used by previous authors. Also, because every semester, the American University of Nigeria holds a faculty assessment/faculty evaluation on every class across all departments to examining the instructors and the student performance.

Student study habit and academic performance
Habits and behaviors adopted by students plays a very Important role in their academic performance. Study habits such as regular study and active learning can positively influence academic performance. [8] Conducted a study which investigated the impact of student study habits on academic performance of university students. This study used student study habits to examine how the factor affects academic performance of university student [8]. I decided to use the factor student study habits in this research to examine how it can impact academic performance of IS students because it has been used by previous author. Also, because the American university of Nigeria has several infrastructures and resource in place to accommodate and support student study habits**.**
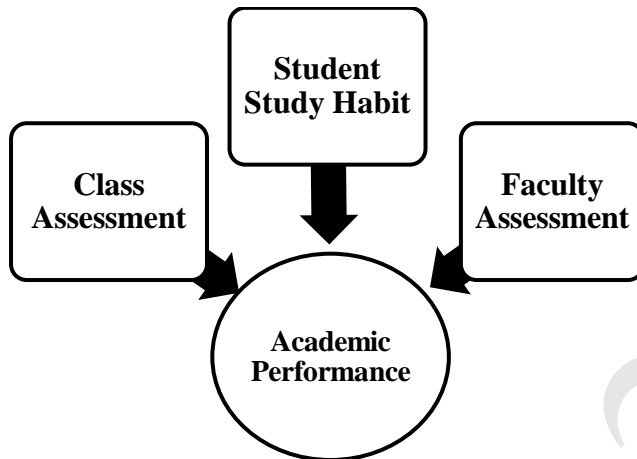
Fig. 17. Conceptual Framework

3   Methodology

The Survey methodology was used to study the academic factors affecting the success of IS students in Nigeria universities. A structured survey questionnaire was used to generate primary data. To provide a description of all the process involved in conducting the research, several stages were adopted.

3.1   Study population, sampling, and data collection techniques

The population of this study consists of all currently enrolled IS student at the American University of Nigeria, Adamawa state. Available statistical data suggest that there are 1035 student enrolled at the American University of Nigeria majoring in different departments. However, there is a total of 100 undergraduate student studying IS at the American University of Nigeria, 70 males and 30 females (Source: American University of Nigeria Registry, Fall 2022). The sample of the study was randomly selected IS undergraduate student at the American University of Nigeria. The sample was made up of males and females, between the age of 16 – 20 years in their first year – 100 level, middle years 200 – 300 levels and final year - 400 level. The sample size also included 80 IS student from the entire population, in the American University of Nigeria. 80 questionnaires were distributed amongst IS student.

Questionnaire Design.
Referring to [18], which held the view that student academic performance can be linked with the use of library and the hours they dedicate to studying this research operationalized academic performance as how well IS student performs and some academic factors can influence academic performance. Further, many researchers around the world have measured the student academic performance through CGPA. [19] is amongst many who used GPA to measure academic performance because their main focus was in the student performance for a particular semester. To ensure the content validity of the questionnaire used to assess each construct depicted in the figure, some items regarding the measurement of constructs were adapted from previous studies and carefully reworded to fit the academic performance context. Past studies suggested that a good scale might result from not only pertinent literature, but also from professional comments. Therefore, this research has gone through rewording and review by my supervisor. The selection and rewording of items were based on three criteria: student's attitude towards their study, source of motivation and participation in academic activities. As a result, the formal questionnaire was organized into two sections, comprised of 24 questions. The first section contained 4 questions used to as a means of identification on where to categorize the respondent. The second section contained 20 question used to evaluate how academic factors are likely to affect academic performance. A sample of the questionnaire used to generate primary data can be found in the appendix section. The extent of existence for all variable in the research field was measured on a five-point Likert scale, ranging from, strongly disagree to strongly agree. Ranging from 1 to 5 strongly disagree (1), disagree (2), neutral (3), agree (4), strongly agree (5) [10].

3.2   Method for Data Analysis

Statistical Package for the Social Sciences (SPSS) was used as a tool for the data analysis. SPSS is widely coveted due to its straightforward and English-like command language and impressively thorough user manual. It provides a plethora of basic statistical functions, some of which include frequencies, cross-tabulation, chi-square, reliability, factor-analysis and bivariate statistics [9]. Until recently, SPSS is used by various researchers for complex statistical data analysis, including the multiple and simple regression analysis. Thus, in this paper, the SPSS was used to conduct a multiple linear regression analysis on the data that was collected. Multiple linear regression is a statistical method used to analyze variable and test the relationships between one dependent variable and multiple independent variables. The independent variables of the study include the academic factors such as student study habit, class assessment, faculty assessment, and student academic performance. The basic form of regression model that captures these variables are presented as follows:

- Predictor, explanatory or independent variables (x)
- Response, outcome, or dependent variable (y)
- Constant or Intercept ($\beta 0$)
- Error term (ε)
- X's slope or ($\beta 1$)

$$\psi = \beta 0 + \beta 1 \cdot 1 + \beta 2 \cdot 2 + \beta 3 \cdot 3 + \Sigma \qquad (1)$$

Where, $\beta 0$ is the y intercept and refers to the estimated value of **y** when **x** is equal to **0**. The coefficient **$\beta 1$** is the regression coefficient and denotes the estimated increase in the dependent variable for every unit increase in the independent variable. The symbol **ε** is a random error component and signifies imprecision of regression indicating that, in actual practice, the independent variables cannot perfectly predict the change in any dependent variable.

3.3   Ethical Consideration

Ethical considerations in research are a set of principles that guide a research designs and practices. These principles may include voluntary participation, informed consent, anonymity, confidentiality, potential for harm, and results communication. An approval was gotten from the AUN institutional review board to carry out this study. A consent was also stated in the questionnaire for everyone to read before they proceed to answering the questions on the questionnaire. The Identity and the image of the respondents will be protected. This is done for any study that is not within the school, in order to ensure the security of the researcher. A faculty approval is also gotten before the data collection. This study took into consideration a number of ethical issues as it pertains to this research. On the issue of non-maleficence, this study ensured that the data collection process did not pose any threat to the academic schedule and plans of the respondents which informed the printed-out copy which the respondents filled at their convenience. Also, to ensure that the principle of informed consent was adhered to, the researcher did not coerce or induce any respondent into participating in the data collection process. As such, all respondents willingly took part in the study. To ensure privacy

and confidentiality, the questions included in the questionnaire did not include the name or identity of the respondents. The implication of this is that respondents were at liberty to fill in the questionnaire under anonymity. In terms of data storage, the collected data was stored in a sealed-up envelope and place under watchful eye. The collected data was not divulged to anyone except the second author of this research for the purpose of verifying and authenticating the collected data.

3.4 Validity of Research Instrument

The validity of the research instrument is the tool used to assess the reliability of the findings based on information gathered from the participants, who are IS students. The validity of research instruments often evaluates whether the collected data accurately reflects the constructs. The instrument is evaluated depending on how well it predicts the data. After entering the data into SPSS, the statistical tool that will be used in this study, the validity will be evaluated. If a set of data measures what it is intended to measure, it is said to be valid.

3.5 Reliability of Research Instrument

The reliability of Research Instrument is the test of the ability of the consistent performance of the instrument in use. Consistency measures how consistently accurate a result is while utilizing a specific tool for statistical analysis. Reliability also refers to an instrument's capacity to take measurements repeatedly under the same circumstances. It demonstrates the reliability in getting outcomes. Using the same instrument, a researcher or another researcher will get the same results, according to credible data. It also demonstrates that the responses are consistently assessing what the researcher wants to measure. After entering the data into SPSS, the instrument's reliability will be determined. Cronbach's alpha or composite reliability are used to determine the dependability. The majority of structural equation modeling research use composite reliability to assess the instruments' internal consistency [9].

4 Research Findings

4.1 Descriptive Analysis

Table 3. Descriptive Analysis (Source: Author's Computation using SPSS 14)

	N	Minimum	Maximum	Mean	Std. Deviation
Gender distribution	80	1.00	2.00	1.3375	.47584
Age distribution	80	1.00	4.00	2.5375	.85601
Level distribution	80	1.00	4.00	3.1875	.96906
Marital status distribution	80	1.00	3.00	1.0750	.30914
Valid N (listwise)	80				
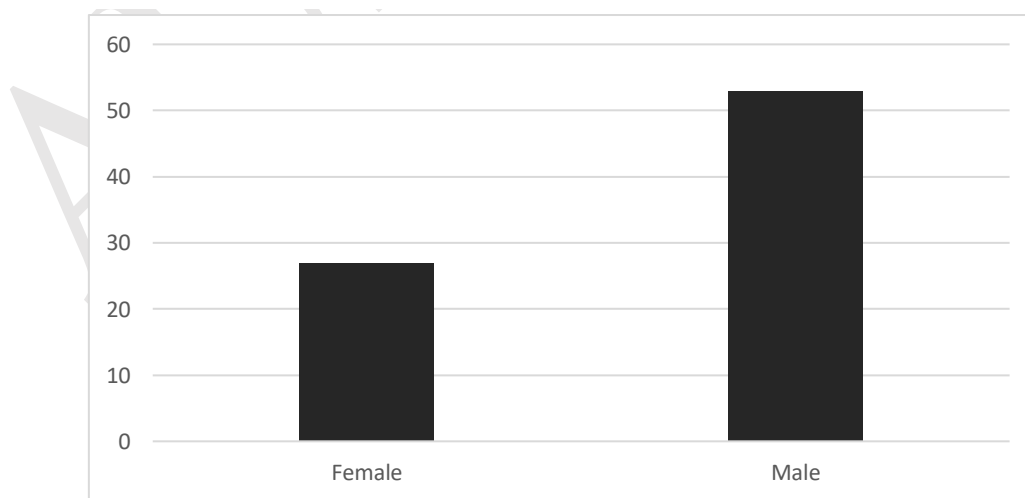
Fig. 18. Sex of Respondents (Source: Author's Questionnaire 2023)

Figure 2 above shows the sex of the respondents. The number of male respondents is 53 and the number of female respondents is 27.
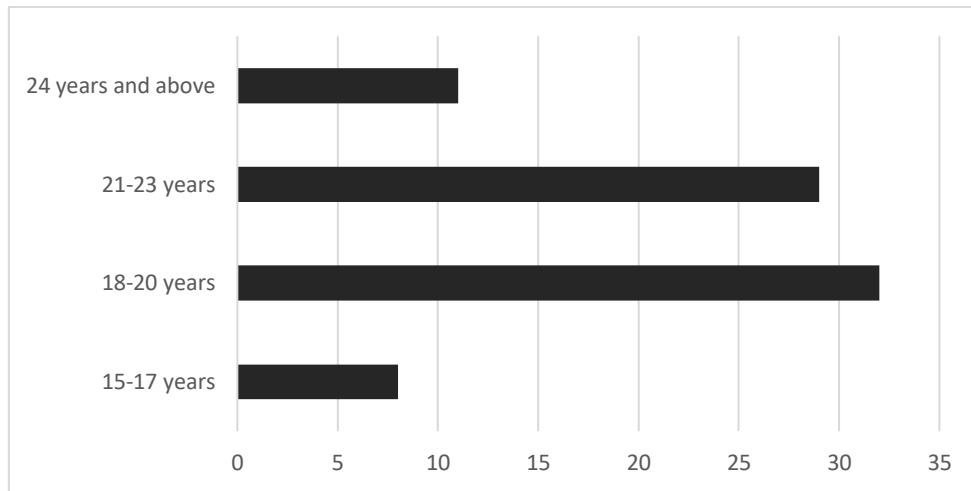
Fig. 19. Age of Respondents (Source: Author's Questionnaire 2023)

Figure 3 above shows the age of the respondents. The number of respondents age 24 years and above is 11, the number of respondents age 21-23 years is 29, the number of respondents age 18-20 years is 32. The number of respondents age 15-17 years 8.
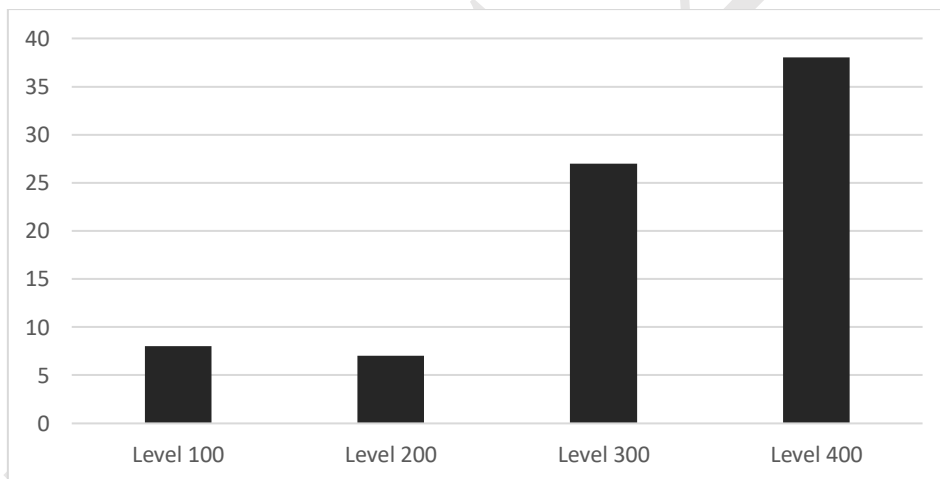
Fig. 20. Current level of Respondents (Source: Author's Questionnaire 2023).

Figure 4 above shows the respondents level of education. The number of respondents that are still in their first year is 8, the number of respondents that are in their Second years is 7, the number of respondents that are in their third year 27, the number of respondents that are in their fourth year is 38.

Fig. 21. Marital Status of Respondents (Source: Author's Questionnaire 2023)

Figure 5 above shows the martial status of respondents, the number of respondents that are divorced is 1, the number of respondents that are married is 4, the number of respondents that are single is 75.

4.2   Predictive Analysis (Regression Analysis and Results)

Components of the Regression Output.

Table 4. Variable Table (Source: Author's Computation using SPSS)

The table presents the variables entered and removed from a regression model predicting CGPA. Three predictor variables, CA, FA, and SSH were entered into the model using the "Enter" method. No variables were removed from the model. The dependent variable, CGPA, is the variable being predicted by the three predictor variables.

Table 5. Test for the Impact of the Independent Variables (FA, CA, & SSH) on The Dependent Variable (CGPA). (Source: Author's Computation using SPSS)

Variables	Coefficients	Standard Error	t -Stat	P-value
Intercept	1.348	0.094	3.683	0.000
FA	0.120	0.110	-1.092	0.278
CA	0.338	0.170	1.992	0.050
SSH	0.193	0.074	2.603	0.011
R	0.438			
R Square	0.192			
Adjusted R Square	0.160			

Durbin-Watson	1.824
Standard Error	0.590
F-Statistics	6.021
P-Value	0.01

From table 3, the coefficient of determination R^2 shows that 19.2% of the impact on CGPA can be explained by the three independent variables (FA, CA, & SSH). This implies that FA, CA, and SSH can be effectively used to control CGPA. Additionally, the F-statistics (6.021) has probability less than 5%, which indicate that the independent variables (FA, CA, & SSH) in the model have significant impact on CGPA from IS student in Yola, Adamawa state, Nigeria. The Regression equation for the impact of each of the independent variables (FA, CA, & SSH) on CGPA from IS student enrolled at the American university of Nigeria is represented in the equation below:

$$\text{ΧΓΠΑ} = 1.348 + 0.120\text{ΦΑ} + 0.338\text{ΧΑ} + 0.193\text{ΣΣΗ} \quad (2)$$

However, the contributions and significance of FA, CA, and SSH in the model is used to test the hypothesis using the t-test. The hypothesis is tested with the coefficient and the t-values.

Hypothesis is Tested with the Academic Factors on Academic Performance.

- H0: There is no effect of academic factors on academic performance of IS students in Nigeria universities.
- H1: There is an effect of academic factors on academic performance of IS students.

On the basis of the beta coefficients, the model shows that student study habit causes a 19% positive variation in the academic performance of IS student and t-value is also significant. Class assessment also causes a 33% variation in the academic performance of IS student the direction is a positive direction. Here t-value is also significant. So, this proves that we can accept the H1 which states that "There is no effect of academic factors on academic performance of IS students in Nigeria universities."

Hypothesis is Tested with the Academic Factors that Predict Academic Performance.

- H0: There is no academic factors that can predict the academic performance of IS students in Nigeria universities.
- H1: There are academic factors that can predict the academic performance of IS students in Nigeria universities.

The results of the research reveal that the second hypothesis is been supported, also the beta coefficients and significant t-values for the academic factors (student study habit and class assessment) suggests that they are predictors of academic performance. Therefore, the null hypothesis (H0) is rejected and the alternative hypothesis (H1) is accepted.

4.3   Discussion of Findings

This study was carried out to explore academic factors affecting the academic performance of IS student in Nigeria Universities. The research was conducted on the IS department of a private university in Nigeria, (the American University of Nigeria) Yola, Adamawa state. Two hypotheses were used in the study to examine the effect of the independent variable on the dependent variable. By using the appropriate statistical package to analyze primary data it was found that class assessment, competency and student study habit are factors that affect the academic performance of IS student. Student study habit and class assessment shows a positive impact on the academic performance of IS student and Faculty Assessment shows a different relationship on the academic performance of IS student but the significant level is high. So, it indicated that the student study habit and class assessment are important factors that affect the academic performance of IS student. Faculty assessment affect the academic performance of IS student, when the instructors are competent it may increase academic performance when they are not competent it can decrease academic performance. In a more detailed explanation the standardized coefficient for FA is -0.127, indicating that for every one-unit increase in FA, the CGPA is predicted to decrease by 0.127 standard deviations, after accounting for the influence of other variables.

5   Conclusion

The results of this study offer an important insight into the academic factors that affect the academic performance of students in the department of IS at undergraduate level. Previous research on academic performance suggest that precollege performance variables can serve as an important predictor of student university success [11]. This may vary across different field and across student at different level and that might explain part of the disagreement between researchers.

Researchers had different result on previous studies about the effect of class attendance on academic performance ([12] [13]), this study contributes to that line of research and coincides with most of their results. This research showed that class attendance (class assessment (comprises of class participation, class attendance class quiz, project and exams)) has an effect on academic performance of IS student. By monitoring the student study habit and class assessment of IS student administration may be able to identify student with poor academic performance, the factor leading to poor academic performance and how to help IS student increase their academic performance at the university.

5.1   Limitations

There was certain limitation in regards to this study. Firstly, the sample size taken in this study was small, that is only eighty (80) IS student. If this study was to be carried out again on a large sample size, I think the results might be improved than existing study. Second limitation of the study, the study was carried out on one state/city i.e. Adamawa state/Yola. I also believe that including other relative factors that affect the academic performance of IS student can improve the results.

5.2   Suggestions and Recommendations

The academic performance of IS student can be improved if the administration of the university, create reading club and encourage the instructors to persuade student into making using of the resources the club may have to offer. That way student can spend a few hours in the club session during the weekends or their leisure time, this would gradually build on their reading/studying habit. Class assessments (comprises of class participation, class attendance class quiz, project and exams) is a very important factor to good academic performance. The administration of the university can help the students by encouraging tutoring session between students, extra activities to earn bonus points and creation of incentive programs.

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The American University of Nigeria's Interventions in Mitigating the Boko Haram Insurgency in Northeast Nigeria: A Case Study of a Development University

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Abstract

The Boko Haram insurgency in Northeast Nigeria has precipitated a complex humanitarian crisis characterized by mass displacement, loss of lives, and socioeconomic disruption. Different development assistance organizations, such as the United States Agency for International Development (USAID), Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), United Nations Development Program (UNDP), and United Nations Population Fund (UNFPA), have intervened to mitigate the adverse effects of Boko Haram terrorism in the northeast and Nigeria generally. These organizations' activities have received scholars' attention; however, the American University of Nigeria (AUN), a development university in the heart of the conflict zone, has received limited critical attention on its roles in combating the Boko Haram menace. This paper holistically examines AUN's strategic interventions in education, community engagement, and peacebuilding, underscoring the pivotal role of development universities in crisis mitigation and community resilience, especially in the developing world. Such initiatives include the Chibok Girls Education Initiative, the Feed and Read program, the Waste to Wealth project, and the AUN Adamawa Peace Initiative (API). Through these humanitarian-centered programs, AUN demonstrates its dedication to fostering human capital, empowering vulnerable populations, and promoting a culture of peace to alleviate Boko Haram terrorism. This research highlights the potential of development universities as agents of positive change in conflict-ridden societies, providing a model for community-engaged higher education institutions seeking to contribute to sustainable development and post-conflict recovery. By uniting research efforts and translating findings into action, AUN exemplifies the transformative power of knowledge and humanitarianism in combating security challenges and building a more resilient future for Northeast Nigeria.

Keywords: American University of Nigeria, Development University, Boko Haram Terrorism, Humanitarianism

1 Introduction

The emergence of Jama'atu Ahlis-Sunnah Lidda'awati wal Jihad, also known as Boko Haram, terrorism in 2009 after the extrajudicial killing of its leader, Mohammed Yusuf, has undermined various forms of development in Northeast Nigeria and caused unimaginable humanitarian crises. Boko Haram terrorism remains one of the most prominent and devastating conflicts in Nigeria since independence (Adeleke & Omobowale, 2023). Some of the harmful effects of the Boko Haram conflicts include limited economic activities in the Northeast, such as restricted access to farmlands (Ikpe, 2017), food shortages in the region and northern Cameroon (Kah, 2017), kidnappings, "furthered displacement of people, and…hampered human developments" (Moshood and Thovoethin, 109). Development organizations, such as United Nations agencies and the United States Agency for International Development (USAID), have mitigated these negative socio-economic effects; however, studies have focalized international organizations' humanitarian interventions more than their local partners. Equally, there are limited studies on the American University of Nigeria's humanitarian efforts to mitigate the Boko Haram terror in the Northeast, especially in Adamawa State. The American University of Nigeria (AUN) is significant and strategic because it is the only development university in the region and connects humanitarian services with education.

AUN, formerly ABTI University, was founded in Yola, Adamawa State, in 2004 and started full-fledged in 2005 (AUN website). Yola is located in Northeast Nigeria, which has been the hotbed of Boko Haram terrorism since 2009. The emergence of Boko Haram poses a tremendous challenge to development in the region. Incidentally, AUN's mission as a development university is to foster holistic development in Nigeria, Africa, and globally. Hence, the Boko Haram conflicts undermine AUN's mission.

Conversely, since Boko Haram's emergence, AUN has intensified its efforts at fostering numerous developments in the Northeast and globally. These developments are premised on different interventions that have served as shock absorbers

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for the region and align with AUN's goal to serve as a university "which would focus on development issues" (AUN website). Our objective in this paper is to examine these interventions through an exploratory approach, which we believe can unfurl more conversations on AUN's contributions to mitigating Boko Haram terrorism in Northeast Nigeria and illuminate development universities as model universities in the developing world for engendering peace and human capital development.

Mazi Ojiaku and Gene Ulasky (1972) trace the history of Nigerians' preference for American education since the 1930s to its practicality, work-study system, and "far greater range of opportunities and superior graduate studies" (383). AUN offers parallel opportunities and, most importantly, prioritizes humanitarianism in the form of community service and other specific interventions. Community service is one of the pillars of AUN as a development university and is positioned as purveying interventions to mitigate Boko Haram's violent extremism. Compulsory community service, voluntary community service, and service-learning are the tripartite community service at AUN. The three forms engender humanitarianism and development of AUN's host communities and region, the Northeast. According to Bronwen Everill and Josiah Kaplan, humanitarianism originated from eighteenth-century enlightenment ideas and entails sympathy for the suffering of the *Other*. They aver that humanitarian actions entail "economic, trade, and social interventions by a variety of actors focused on 'development'" (3). Although they raise other pertinent issues on the controversies surrounding humanitarianism, this study focalizes their argument about humanitarian intervention as a source of development.

AUN, as a development university, partners with other development partners to provide humanitarian interventions in northeast Nigeria since the Boko Haram onslaught. While many studies have been conducted on the impact of Boko Haram in the northeast and Nigeria, there is a need to explore the contributions of AUN in mitigating the effects of Boko Haram in the region. The case of AUN as a model development university that intervenes during a violent disaster should be a case study for the essence of development universities in the developing world. It is expedient to explore AUN's humanitarian interventions holistically, such as the Chibok Girls Education Initiative, which empowers girls abducted by Boko Haram (Dauda, 2024), the Feed and Read program, which provides nutritional support and literacy education to displaced children (Global Partnership for Education, 2020), the Waste to Wealth project, which promotes economic empowerment for women (RESWAYE, 2021), and the AUN Adamawa Peace Initiative (API), which fosters interfaith dialogue and community-wide cooperation (Udo-Udo et al., 2020). Exploring these interventions holistically will illuminate AUN's strategic position in lessening the vile effects of Boko Haram terrorism in Northeast Nigeria.

2 Development Universities, Conflict Societies, Humanitarianism

A development university is a higher education institution actively engaged in research, outreach, and community development initiatives to address societal challenges. A development university such as AUN occupies a strategic position in a conflict environment to foster community development. Although the precise origin of universities has been controversial, the first formal incarnation of a university has been traced to Peter Abelard's intellectual activities at the University of Paris (Scoyoc, 1962). However, the idea of a university has different meanings in different societies. According to James Coleman (1986), citing Clark Kerr, there are three ideas of a university. The first is Cardinal Newman's idea of a university that stresses teaching and a liberal education but excludes research and service. The second is Abraham Flexner's idea of the modern university, the German model that stimulates advanced research but opposes community service. The last is the American idea of multiversity that promotes service to society. However, Coleman identifies the fourth variant as the development(al) university, which is practically concerned with proffering concrete solutions to societal problems for development. AUN combines the community service feature of the third model and Coleman's fourth variant. AUN's goals of providing community service and finding concrete solutions to society's problems to engender development position it as a development university that alleviates the Boko Haram crises in Northeast Nigeria.

Coleman traces the origin of developmental universities to three traditions. The land-grant movement of the mid-1860s in the United States dictated that universities should find solutions to and develop societies, representing the first tradition. The second is in the foundation law of Japan's first university, prioritizing development as the focus, while the Soviet model is the third. The last tradition perceives a university as alleviating social inequalities and socializing students to serve the state. In the three traditions, development is a keyword geared toward developing societies. In developing countries like Nigeria, development universities are a model that can subvert conflicts and entrench developments. USAID and other development organizations have sponsored aid programs to promote these development aspects of universities. However, many universities in developing countries prioritize teaching and research but neglect service to society. Coleman's argument signifies the cardinality of development universities in developing countries, especially in conflict zones.

Tristan McCowan (2019) also contends that the development university is the best model for developing African societies, especially for achieving the Sustainable Development Goals (SDGs), which terrorist groups like Boko Haram undermine. McCowan reveals that the terminology may differ in different contexts ranging from civic university to utilitarian university; the ultimate aim is to merge service and development in universities. The features of the development(al) model of universities encompass "commitment to public service, its focus on the most marginalized in society, and its emphasis on application of knowledge and impact on non-academic communities" (McCowan, 93).

There are limited scholarly studies on the roles of development universities in conflict zones in developing countries. AUN implements the development-university ideas but has received limited studies as a model in the developing world. For example, McCowan examines the University for Development Studies in Ghana and the federal universities in Brazil. Eric Fredua-Kwarteng also focuses on Ghanaian universities as models. AUN's positionality in Northeast Nigeria makes it an institution that should be studied in apprehending development universities' roles in conflict zones in developing countries. This research aims to illuminate the link between AUN as a development university model and its humanitarian interventions in lessening the harrowing effects of Boko Haram terrorism in Northeast Nigeria and promote more scholarly research on these interventions.

3 AUN's Comprehensive Response to the Boko Haram Insurgency in Northeast Nigeria

The Boko Haram insurgency in Northeast Nigeria presents a complex challenge, intertwining socio-economic disparities, religious extremism, and the critical role of education in conflict and peacebuilding. This essay examines the multifaceted interventions of the American University of Nigeria (AUN), as a development university in a conflict zone, in mitigating the insurgency's impact and fostering long-term stability in the region. AUN's comprehensive approach, encompassing innovative educational initiatives, community engagement, and targeted development programs, contributes to a holistic framework for community resilience and sustainable development. This approach equally valorizes the significance of development universities as a model for subverting conflicts and engendering SDGs in developing countries.

4 The Paradox of Western Education and Boko Haram

Boko Haram's emergence in the early 2000s was fueled by a complex interplay of factors, including poverty, corruption, and a rejection of Western education perceived as a symbol of colonialism and inequality (Kyari, 2011). This rejection manifested in violent attacks on educational institutions, further destabilizing the region. The tragic abduction of the Chibok schoolgirls in 2014 epitomizes this assault on education, highlighting the vulnerability of students, especially girls, in the face of extremism. However, the challenges to education in Northeast Nigeria extend beyond security concerns. A pre-existing lack of access to quality education, coupled with language barriers and inadequate resources, created an environment where extremist ideologies could take root (National Education Data Survey, 2010).

AUN responded to these challenges with innovative programs like the Students Empowered through Language, Literacy, and Arithmetic (STELLAR) and the USAID-funded Technology Enhanced Learning for All (TELA). STELLAR focused on improving early primary education through after-school tutoring, bilingual reading materials, and technology integration. TELA expanded this approach using radio broadcasts, mobile classrooms, and community facilitators to reach a wider audience, including displaced children. These initiatives highlight the power of community-based, contextually relevant education in conflict zones. By addressing the specific needs of affected communities, AUN demonstrated that education can be a powerful tool for resilience, peacebuilding, and development (AUN, 2012).

5 American University of Nigeria Atiku Institute for Development (AUNAID): A Catalyst for Peacebuilding and Development

AUNAID, AUN's development arm, has been instrumental in addressing insurgency's long-term social and economic consequences. Recognizing the interconnectedness of education, health, and economic empowerment in peacebuilding, AUNAID has implemented various programs designed to rebuild communities and foster sustainable development. These programs are organized in partnership with different local and international development organizations. Collaborations with humanitarian organizations enhance community resilience and promote social cohesion.

AUNAID stimulates peacebuilding and reintegration programs. AUNAID's peacebuilding initiatives focus on restoring stability, reintegrating displaced persons (IDPs), and addressing the root causes of conflict (Usman et al., 2024). Vocational training programs provide IDPs and former insurgents with essential skills for economic reintegration, reducing the likelihood of a return to violence. A veritable example is AUNAID's Waste to Wealth. The Waste to Wealth program empowers women by providing recycling and waste management training. This initiative enables women to generate income while promoting environmental sustainability (RESWAYE, 2021). The program fosters social cohesion and contributes to community development by addressing economic and environmental challenges.

AUNAID also fosters health interventions. Recognizing the link between health and peacebuilding, AUNAID has implemented health interventions in IDP camps. The oral hygiene initiative at Malkohi IDP Camp, a collaboration with WHO and local healthcare providers, addressed immediate health needs and promoted long-term well-being through hygiene education (Tyndall & Inyang, 2019). By improving the health of IDPs, AUNAID contributes to their reintegration and the overall peacebuilding process.

Educational Initiatives is another AUNAID's humanitarian effort. AUNAID's educational programs have been remarkably successful in addressing the specific needs of children and youth affected by the insurgency. The Chibok Education Initiative, for instance, has empowered girls abducted by Boko Haram with psychosocial support, vocational training, and access to higher education (Dauda, 2024). The Feed and Read Program combines literacy education with nutritional support for displaced children. TELA, which leverages technology to educate out-of-school children and vulnerable populations, has also shown promising results. As Udo-Udo Jacob and Ensign (2020) argue, utilizing radio for instruction, especially in conflict zones, allows flexibility and adaptability, ensuring educational continuity despite disruptions. TELA exemplifies this approach, demonstrating the transformative power of education in fostering resilience, empowering individuals, and promoting long-term stability.

6 Community Engagement and the Adamawa Peace Initiative

AUN's commitment to peacebuilding extends beyond its campus and into the heart of the community through the Adamawa Peace Initiative (API). Formed in 2012 in response to the growing threat of Boko Haram, the API brings together Muslim and Christian leaders, community members, and AUN representatives to address the root causes of conflict and promote peace through education and dialogue (Udo-Udo et al., 2020). The API's work is guided by several fundamental principles: youth engagement, education as a foundation for society, the centrality of women in development, and the potential for religion to be an instrument of peace.

Through initiatives like "The Peacemakers" television show, Peace through Sports, ICT training for vulnerable youth, and support for the Chibok girls, the API actively promotes peace and counters extremist narratives. By facilitating community-wide cooperation and providing platforms for dialogue, the API fosters resilience and demonstrates the power of collective action in building a more peaceful future (Udo-Udo et al., 2020).

7 AUN's Commitment to Research and Knowledge Exchange

AUN is committed to fostering interdisciplinary research and knowledge exchange to address the complex challenges of conflict and peacebuilding. The American University of Nigeria International Conference (AUNIC2024), themed "Uniting Research Efforts: Combating Security Issues in the North-East of Nigeria," brought together researchers from various fields to generate insights and identify practical interventions for promoting peace and stability (American University of Nigeria, 2024). This conference aims to produce scholarly insights that will further mitigate the effects of Boko Haram.

8 Conclusion

AUN's comprehensive response to the Boko Haram insurgency is a testament to the transformative power of education, community engagement, and multifaceted interventions in fostering peace and sustainable development in conflict-affected regions. By addressing the immediate needs of vulnerable populations and contributing to long-term community resilience, AUN plays a vital role in rebuilding Northeast Nigeria and creating a more stable and prosperous future for the region. The plight of the Chibok girls serves as a poignant reminder of the importance of this work and the need to protect education from the forces of extremism. This inspiring work underscores the importance of continued investment in these initiatives and ongoing research and collaboration to ensure lasting peace.

This research also underscores the significance of development universities as a university model for ameliorating development issues in developing countries. By deploying AUN as a case study, this paper contends that universities in conflict zones must combine developmental policies and humanitarian practices to undermine conflict and its devastating effects. Significantly, universities' adoption of development and community service policies will foster achieving SDGs in developing countries.

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Discursive (De)construction of Identity in Ethno-Religious Crisis Discourses on Online Citizen Media in Nigeria

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Abstract

Ethno-religious (ER) crisis discourses in new (citizen) media spaces in Nigeria are known to implicate identities of groups that share religious, ethnic and regional affinities with crisis situations and perpetrators. This paper interrogated how actors position self-group in the identity construction discourse vis-à-vis ER crisis discourses orchestrated by online citizen media. This was done to accomplish two objectives: (i) to understand how groups construct/(re)negotiate their own identities and deconstruct others', and (ii), to uncover the discursivity and linguistic strategies that play out in the whole discourse process. Nine reports were downloaded from six citizen media sources: *Legit, Nairaland, BellaNaija, Morning Star News, The Nigerian Lawyer* and *Worthy News*. The ER crises were published between 2014 and 2016—a period that was largely characterised by very rife ER crises in the country, particularly in the northern Nigeria. The study analysed the relevant headlines, main stories and readers' comments, by appropriating on the data, the Norman Fairclough's three-dimensional model of critical discourse analysis—a framework that theorises discourse as *text, discursive practice* and *social practice*. The finding evinced that discourse actors deployed discursive practices of interest consciousness, identity reinforcement, identity association/support and identity defense to negotiate and construct self-group images, and utilised framing to deconstruct other-group's identities. It also uncovered various role that linguistic devices such as metaphor, interdiscourse reference, dysphemism, lexicalisation, collocation, transitivity, deixis and nominal elements, as well as the discourse strategies of verbal attack and vindication of self-group played in giving effect to discursive (de)construction of identity. The finding also underscored that identity (de)constructions in ER discourses drives ideological manifestation. This is because social actors participate in discourse within ideological divide by discursively establishing their identities in support of the ideology of the group to which they subscribe. The study concludes that away from reiterating the obvious impact of citizen media on social advocacy and civil action, the paper evinced that crisis discourses on citizen media are vastly rich in language use, especially for identity representation, negotiation and or deconstruction. The cyber freedom which citizen actors also enjoy spurs their contribution to social conversations, and accommodates ideological languages with which they take sides in such conversations. However arguably, the language use arising from identity (de)construction in ER crisis discourses is a potential 'cold war' that proliferates prejudice, incitement, aggression and or hate speech, all of which further widen the social cohesion/integration gap.

Keywords: *identity, ideology, ethno-religious crises, crisis discourse, citizen journalism, citizen media, discursive practice, critical discourse analysis*

1. Introduction

For operational definition, *identity* is broadly considered in this study to cover how a person or group perceives itself, the *image* it projects to others and the *reputation* others make of the group (Fan, 2010) even though these constructs are somewhat different 'mental associations generated by knowledge and experience' (Adegoju, 2016: 2). From the light of self-perception, identity comprises the qualities associated with a person/group, which make them socially different from others, or the sense of belonging to a group as against another; hence, resulting in social stratification. It provides an explanation for who people are, what a group is or what it projects itself to be by virtue of its (in)actions and reactions in a given social situation. We all have our identity rooted in social structure and it is disclosed with our thought, action and speech. The identity we construct for ourselves is often informed by the expected social norms in every kind of discourse—inter-personal, inter-group or public sphere discourse (Norris, 2008). It is these norms that social actors or participants adhere to when constructing their personal identity. Furthermore, Wodak and Mayer (2008: 26) stress that identity constitutes what is called *social representation*. The notion, they note, was a coinage from Serge Moscovici (1981) to mean 'a bulk of concepts, opinions, attitudes, evaluations, images and explanations which result from daily life and are sustained by communication'. Social representations are common ties shared by members of a social group. They are group-specific, and are not applicable to the whole society. The representations are a core element that constitutes individual's social identity by virtue of identifying with the group whose members share these indications. This is what Durkheim, cited in Wodak and Mayer (2008: 26) means, by stating that 'the ideas…are not personal and are not restricted to me; I share them, to a large degree, with all the [people] who belong to the same social group that I do. Because they are held in common, concepts are the supreme instrument of all intellectual exchange'.

With regard to a group's reputation in the eyes of others, identity includes the description that others place on a particular group as a result of the ideology such group subscribes to. Indeed, both ideology and identity share a tiny boundary; ideology actually forms the basis of identity because when social actors are participating in discourse within the ideological divide, they do so by establishing (either subtly or unequivocally) their identities in support of the ideology they subscribe to. In other words, identity can be ideological. By this, we mean the representation of a certain group that subscribes to a socio-political ideology, school of thought or philosophy. Identity and or membership is clearly a reflection of 'who belongs to the group and who does not, who is admitted to the group, and who is not…?' (van Dijk, 1995: 249), and that this is what operates in the cases of racist or nationalist ideologies wherein the ideologists do not see others as equal to them. Also, in social issues, such as ethno-religious ones, there is always no middle ground - all participants are identified with one side or another other. More so, aside from age, class and gender, ethnicity and religion are some elements of social identity that can influence decisions. This plays out for instance, where people favour members of their religious group (i.e. social bias) when social needs arise, as a way of affiliating with them (Emmons & Paloutzian, cited in Emeka-Nwobia, 2015: 25).

There are different significations for the term *ethnicity* in literature, one of which defines it as a 'community of people who share common cultural and linguistic characteristics including history, tradition, myth and origin' (Ogunbunmi, 2013: 326). This definition is not at variance with Thomson's (2000: 60) view of what basically constitute an ethnic group. Thomson notes that aside from upholding the same history (and maybe language), the people relating under the same ethnic roof have common conviction that they are sharing an identity that fate bestowed on them by virtue of their origin, kinship, ties, traditions and cultures. An ethnic group is a people that are '…different in every way, including religion, custom, language and aspirations', ideology, and or geographical region—all of which are noticeable features of a group members' identity (Porter, 2011). The second term, *religion*, gives a general description of the belief in the existence and worship of sacred things or supreme beings—idols, deities, God, gods or divinities—believed to operate with unfathomable powers that can orchestrate natural phenomenal or control human affairs, and to which man believe he has to pay obeisance and subservience if he must enjoy a peaceful earthly existence, live morally and perhaps get rewarded in the afterlife. In other words, religion poses a relationship that knots human beings to supernatural forces. This observation is also attested in Williams' (2013: 2) definition that religion is 'man's relation to divine or super-human powers and the various organised systems of belief and worship in which these relations are expressed'.

The combination of both constructs, in terms of friction generated as a result of preserving creeds and protecting the interest of an ethnic group to the detriment of others, constitute *ethno-religious* (henceforth, ER) crisis. In Nigeria, ER crises are some of the varied shapes the trajectory of conflicting relations have taken. These crises are cracking down the ominous fragility of Nigeria's social cohesion. Ethnic crisis is a quagmire so entangled in the web of religion, language and identity that only conscious efforts can forestall it. No ethnic group is menace-free; all ethnic groups are something of a problem for Nigeria's achievement of national cohesion (Achebe, 1983:45). Thus, ER discourse, among other issues, comprises series of discussions on surges and actors involved, various opinions, reactions and counter-reactions to crisis development, and perspectives to resolutions from citizens and other stakeholders. The Nigerian citizen media whose reports are selected for this study deploy their online platforms to this discourse.

The term, *citizen media*, also called citizen journalism, is the participation of citizenry in the activities of collating and disseminating news not routinely as a paid /trained journalist would do, but intermittently or by happenstance, as a considered form of civic responsibility (Markham, 2009), to produce a society that is more socially and politically aware than in the past. It is the self-reporting of happenings in their localities – self-reporting because 'individuals [or group] on their own create web pages where they publish news material [that were] collected' using their personal 'mobile phones and other recording materials which enable them to snap and cover events' (Onyebuchi, 2010). The need for civic engagement in journalism is necessitated by the unprecedented growth of the modern world in all spheres, which has provided a massive terrain whose total exploration is highly impossible if left alone in the hands of the traditional media to uncover. Since the engagements of citizens in journalism are mere patriotic efforts that do not attract any compensation, citizen journalists are commonly fascinated by crisis situations. Thus most times, the reports are any kind of 'crisis, social injustice and anomalies within their community' (Adeyeye & Christian, 2017), including accidents and crimes, as well as outbreaks of other horrendous incidences. For instance, Dare (2011) relays how the social media outran the print media in revealing the news of plane crashes—the Belleview and Dana airlines in 2012. Also, 2012 fuel subsidy protest *Occupy-Nigeria*, 2014 *Bring-Back-Our-Girls*, 2020 #EndSARS protests and Lekki Massacre, among other incidents were strengthened by the online continual updates of individual journalists who alongside their reports muster Nigerians to take part in the protests. 2016 *Stop-Xenophobia* in South Africa was another protest supported by the efforts of both diasporic and home-based citizen media in a bid to attract global attention to the discrimination and dehumanisation Nigerians face in the hands of their host, South Africans.

Civic engagement remains a laudable concept about the involvement of citizens in their very own matters, and the citizen journalism spaces among other new media platforms have, just as elsewhere in the world, undoubtedly engendered this reality in the Nigerian socio-political landscape. New (citizen) media is another term for social media or mediated platforms that "permit interactive participation of users who are no longer mere passive recipients of information, but active participants in the production and sharing of information" (Ayoola, 2018: 22). It encompassing digital avenues such as blogs, Twitter (X), Facebook, Nairaland and others, which are enabled by the Internet and

technology-based communication gadgets. The information flow via new media has had unprecedented sway on civic engagements of the Nigerian public, especially in socio-political issues. Unlike in the pre-social media era, new citizen media have made possible increasing participation and interactions on public matters (Ifukor, 2010; Chiluwa 2012); They have provided affordances for individuals to contribute to, discourses on crisis situations (such as ethno-religious conflicts, terrorism and crimes) among other discourses bordering on security, governance, and socio-economic and political life of the country, particularly those threatening the development and the existence of our common cohesion. This further advances the frontiers of public enlightenments and gradually obliterates the hitherto concern that the Nigerian citizenry, especially the youths, barely engaged in civic engagement and nursed apathy in the machineries of the government.

Imperative to this study however, is the observation that citizen contributions and engagements in crisis discourses via citizen media spaces has culminated in crisis discourse actors generalizing, associating and appropriating the image and identity of crisis perpetrators with communities, regions, tribes and individuals sharing religious, ethnic and regional affinities with perpetrators (Christian, 2018). This engenders narratives that impact untowardly on the humanity and perception of people associated with or implicated by crisis situations, especially ethno-religious crises and terrorism, particularly in terms of besmirching a group's identity. In the same vain, an out-group also utilise such spaces to re-negotiate identity, redeem their image, pre-empty negative perceptions and counter attack the in-group.

2. Language Patterns and Identity Construction in the Discourse on Social Issues

Language use plays an invaluable role in identity construction. Pronouns are, for instance, obvious linguistic devices usually used as representations of two oppositions, and members align their identity with them (the groups). Members associate themselves with either *Us*-group or *Them*-group (van Dijk, 2004: 43). Norris (2008) uses the term *identity elements* to refer to pronouns. Pronominal elements have received attention in different theories of personal identity (cf. Mead, 1974, cited in Norris, 2008). As Norris (2008) observes, Mead, particularly, provides a clear scenario for the use of 'I' and 'me':

> the 'I' gives a sense of freedom, of initiative. The situation is there for us to act — in a self-conscious fashion. We are aware of ourselves, and of what the situation is, but exactly how we will act never gets into experience until after the action takes place. Such is the basis that the fact that the 'I' does not appear in the same sense in experience as does the 'me'. The 'me' represents a definite organisation of the community there in our own attitudes, and calling for a response, but the response that takes place is something that just happens. There is no certainty in regard to it. There is a moral necessity but no mechanical necessity for it. When it does take place then we find what has been done. (Norris 2008:140)

There are other linguistic elements and structures that often give participants away in discourse. For instance, speakers in talk, especially political talk, use rhetorical strategies to market both their identity and that of the party they belong to. Also, Tenorio (2011:205) studies transitivity and underscores the way people use it to position themselves. He notes that it is a way of knowing 'how you see the world and how you perceive others'. In addition, lexical selection and syntactic patterns of language are also capable of disclosing the social background and identity of a speaker (Fairclough, 1992). Therefore, identity construction is widely covered, not only in critical discourse analysis but also in discourse studies generally. In fact, discourse studies are full of various perspectives to identity. Hamilton (1998), and De Fina, Bamberg and Schiffrin (2005) examine at different times, the individual side of personal identity, disclosing how individuals craftily deploy pronominals to register their identity and affiliate themselves with one group or another. Wodak et al. (2000) work on national identity construction using social and historical perspectives to analyse national identity while some other scholars bring in socio-psychological and sociocultural perspectives to analyse identity (see Hall & Bucholz, 1995).

With respect to the Nigerian experience, extant studies have, by using discourse analytic methods, underscored identity construction, negotiation and framing, relative to Nigerian socio-political and economic situations in discourse on digital civic engagement, among other research opportunities which the interaction and participation of online users provides (Adegoju, 2016; Odebunmi & Oloyede, 2016; Chiluwa, 2014; Taiwo, 2012; Ugah, 2019). Some of these are the linguistic and discursive human behaviours which, as Taiwo (2010: 72) discovered, include but not limited to 'identity construction, gender consciousness, enactment of power, building of trust, collaboration, aggressive behaviour, and so forth'. Although these studies centre on different national issues, they have a common ground that put discursive practices and language use at the centre of all kinds of identity issues—constructing identity for self or affiliate group, warding off negative image of self-group, negotiating identity or framing the identities of others, mostly for ideological advantage. Adegoju (2016) applied Norman Fairclough's tripartite model of critical discourse analysis to investigate how

the Nigerian public discursively resist the rebranding Nigeria campaign intended to acquire a positive national image for the country in the global eye, and redefine a national identity to mean domestic policies that are sensitive to citizenry plights and leadership needs, which the discourse actors projected as jettisoned/missing in the said rebranding campaign – thus projecting such national effort as a misplaced priority. The study highlighted how, in the negotiation process, the discourse producers – Nigerian public – remained passive about their own contribution to national development and only appeared as recipients of the role of others – the political class. Another study, Odebunmi and Oloyede (2016), used a multi-dimensional theoretical perspective, to explore the different 'pragmatic strategies…, (multimodal) critical discourse inventories and systemic functional resources' (Odebunmi & Oloyede, 2016: 286) and how the mainstream newspaper utilised them to frame the Boko Haram sect as manifesting multiple negative identities—as terrorists, political thugs, criminals and religious extremists—and project it as a distinct terrorism brand. The study concluded that an effective approach that would defeat the sect must take cognisance of the context of the sect's varied identity manifestations which have long made every attempt to curb the sect's activities abortive. Besides, using computer-mediated discourse analytic (CMDA) approach to study the data on weblogs and discussion forum in order to investigate ethnic identity, Chiluwa's (2014) finding showed that by deploying 'code-switching, proverbs and ethnic labels to project their uniqueness' in the discourse on socio-cultural issues, the members of the Igbo extraction are able to better negotiate their hitherto 'perceived endangered identities' (Chiluwa, 2014: 81). Similarly, Taiwo (2012) also adopted CMDA to, among other observations, examine how diverse participants in online discussion forum, *The Nigerian Village Square,* used Nigerian Pidgin, code-switching, humour, idioms and coinages – which are strands of both Nigerian English and indigenous languages – to construct and consolidate their Nigerian socio-cultural identities.

However, the research gap left by these studies is that they are neither concerned with identity scramble in discourses of ethno-religious clash of interests, nor focused on crisis news reported by citizen journalists. To fill this gap, the present study is interested in how discourse producers position self-group in the identity construction discourse vis-à-vis ER crisis discourses orchestrated by online citizen media. Thus, it attempts to provide responses to the following posers: how do groups construct and redeem their identities as well as deconstruct others'? What discursivity and linguistic strategies play out in the whole discourse processes?

3. Methodology

Data for the study are selected citizen media reports, opinions and articles on ethno-religious crises in Nigeria between 2014 and 2016. This period was largely characterised by very rife ethno-religious crises in the country, particularly in the northern Nigeria. Out of many citizen media that published news on ER crisis in Nigeria as Google search result revealed, the researcher selected six (6) sources: *Legit, Nairaland, BellaNaija, Morning Star News, The Nigerian Lawyer* and *Worthy News* (see appendix for the web links). The sources were selected for attracting considerable treads of comments from readers on their ER news, which thus indicates they well engaged the readers. Total sample size of nine (9) reports was downloaded from the six (6) citizen media sources. This was purposive as only the news of ER crises that struck between 2014 and 2016 were considered. The paper subjected the relevant headlines, main stories and readers' comments to analysis. The analysis drew insights from Norman Fairclough's *Discourse as Social Practice* method of doing a critical discourse analytic study.

4. Theoretical Insight

The framework guiding the study is Fairclough's the tripartite model of CDA, which states that discourse can be analytically understood as text, discursive practice and social practice (Fairclough, 1992). As text, discourse underscores different linguistic features that have meaning potentials come into play. They include but not limited to vocabulary patterns, syntactic and grammatical arrangements, cohesive devices and text structural properties. This dimension, as Fairclough (1992:76) puts it, has meaning implication on the overall function of discourse. Discursive practice covers processes of producing and consuming text, as well as the nature of these processes, which vary according to social factors. By this, we mean the interpretation actors give a text, the meaning readers construe of text as well as the effect it has on them. A text that changes the attitudes, beliefs or practices of people is extra-discursive, while the ones with aesthetic, rhetoric and motivating effect are discursive. In analysis, it is expected that discursive practice connects the relationship between the other two dimensions. As social practice, discourse manifests ideological effects and other social enactments such as identity and power play, which are properties of the structure of discourse. Discourse features in the relations of ideology and power, and discursive practices are 'material forms of ideology' (Fairclough, 1992: 87) – that is, they are ideologies that materialise themselves as discursive practices. Construing discourse as social practice would also mean there holds a relationship between discourse and social structure, and this relationship is somewhat dialectical for two observable reasons. One, social structures (in whatever dimensions, e.g., social classes, ethnic group, religious blocs, gender groups, among others) inform the nature of discourse. Two, discourse also shapes social structures because of its being socially constitutive. Following this model, the analysis of the data entails 'a…description of the language of text, an interpretation of the relationship between the discursive processes…and the text, and an explanation of the relationship between the discursive processes and the social processes' (Ayoola, 2008: 60).

5. Analysis of Findings

One observable discursive practice of identity construction is **group's interest consciousness**. This is the manifestation of identity/class consciousness (Taiwo, 2012) in a discourse, wherein a group of people, in protecting their common interests, aspiration, demands, expectations, agitations, needs and rights, justify themselves as people seeking a better course and discursively discriminating the other. It is an ideology of interest, which often surfaces whenever public discourse brings people with conflicting interests together. Clouded by their interests, discourse producers often attack one another, rather than tackle the very social issues for which the discourse was initiated. This is evident in the reactions of the participants in the excerpt below:

EX1

R1: "Every expired nation always has crisis until them separated [sic]. Nigeria is expire nation [sic], no tribe will repair it unless we separated."

R2: "Our police are weak the riot started since last night and police fail to stop them [sic] army came here just under 1 hour everything die dawn."

R3: "There is too much ethnic sentiment here. Please, can't we talk reasonably like people who value human lives? Remember we have no other place we can call our country. Let us not glorify those causing this senseless killing."

R4: "Do you people think that divisions could stop this? No, first you guys said once Buhari comes back bombs will stop. Now the stupid guys who know and right [sic] thinking about how to divide the country as a nation. Just note this. These are the signs of end time. Let pray and let Nigeria remain still [sic] God comes."

R5: "Yoruba and Hausa clash! Yoruba are slave in their own land. Hausa's are taking over."

R6: "One love one nation, if you don't like go to lagoon and sink."

R7: "Waooo president and vice president are fighting. God help Nigeria."

R8: "Osibanjo boys vs Buhari boys."

R9: "Let's talk reality right now... From the beginning there was nothing like one Nigeria and there is still nothing like one Nigeria, it is just a concept that the white man formulated, the truth is that we are Africans and "ethnicity" is inborn in African man. So let's stop the pretense and deceiving ourselves, there is nothing like "one Nigeria." (*Legit*, 2016)

The excerpt contains the reactions to the Hausa-Yoruba clash in Mile 12, Lagos. It is observed that the reactionists' comments (labelled R1-R9) are laden with the **consciousness of interest and polarisation**. Hence, where their interests differ, they pose verbal attack against one another. The actors are clearly skeptical of the unity of Nigeria, and in the way they describe the country; readers easily deduce they are instigating separatism. R2's description of the Nigerian Police obviously lampoons its failure as being incapable of discharging its duties in the face of insecurity and chaos. This further impresses the general insinuations that Nigerians have lost trust in the security system because police officers will never show up when it really matters most. While Rs 3 and 4 agitate the unity of Nigeria, R3 further poses a humanitarian ideology that victims of the clash deserve sympathy, even if Nigerians do not agree under the same political/leadership umbrella. The Yoruba ethnic group is the target of R5. S/he seems to brew ethnicism with his/her description of the group as 'slave'. This metaphorical insulting nominal element implies the weakness of the ethnic group, which the actor projects as the reason the group is subjugated by Hausa migrants, whom it (the Yorubas) accommodated in its ancestral land. R6 appears a direct reaction to R5's comment as a counter-insult on the Igbos with inter-discourse reference to Oba of Lagos' heavy incautious threats on the Igbo residents that they would 'die in the lagoon' on their failure to vote for the then 2015 Lagos gubernatorial aspirant, Ambode. Rs 7 and 8 see the clash more as a division between the two ethnic groups (Hausa and Yoruba, as represented by the then President Buhari and his Vice, Osinbajo) that were in incumbently in power, who were expected to be at least united owing to their common political

bond. More obvious in the excerpt are the attempts by discourse actors to use the crisis to advance varied interests such as separatism and politicking, rather than shed handy insights on the crisis.

Similar to interest consciousness in the data is **the use of identity reinforcement**. By this we mean 'how identities are produced and…imposed on individuals and groups through dominant discourse practices and ideologies' (De Fina, Schiffri & Bamberg, 2006, cited in Chiluwa, 2014: 91). This is the case of excerpt 2 where discourse actors renounce a national identity, and do not only establish their own sectional identity, but also discursively reinforce it:

EX 2

R1: Incredible! Onitsha is as quiet as a grave yard, deserted. Biafrans are mean.

R2: At Onitsha here no movement, all the markets was shut down including the biggest market in West Africa main market, both schools, banks, in fact no movement. Biafra is too much.

R3: Omagba z like a deserted area, no vehicle even kekenapepe to carry those saboutouers [sic] to their different areas. Everybody z at home, shops shut, schools both public and private are on hardlock. I am reporting from Omagba in Onitsha north Anambra state Biafra land.

R4: Everywhere is shut down, everybody is indoor listening [to] RADIOBIAFRA. (*Legit*, 2015)

In the text wherein a sit-at-home demonstration is reported, the ideological stance of the Igbos manifest in the way the group reinforces its identity. The reactionists (R1-R3) in excerpt 2 seemingly support the group in redefining and establishing a new identity; they deliberately negotiate, by means of language, a new national identity for the Eastern Nigerians. They also establish a geo-political identity for the group by referring to Anambra State, one of the Nigerian states, as 'Biafra land'. Citizenship identity is also negotiated for the Eastern Nigerians with the way one of the discourse producers call them *Biafrans* as in 'Biafrans are mean', rather than call them Nigerians. This negotiation is a deliberate attempt to renounce the original identity of the Easterners as Nigerians, accentuate an existence of the defunct Biafra State, and instantiate regional power over Nigerian territory. In this excerpt, there is the use of dysphemism, as the group attempts to magnify the actions of its members using emotive adjectival element 'incredible!', positively hyped statement 'Biafra is too much', and exaggerated similes 'Onitsha is as quiet as a grave yard' and 'Omagba z like a deserted area…' The exaggeration is not in the sense of the words but in the sense of the actions which the words have been used to describe. Similarly, the expressions 'everywhere is shut down' and 'everybody is indoor listening [to] RADIOBIAFRA' are sweeping statements that generalise situations and actions as though they were applicable in all cases or to everyone. For instance, rather than use 'majority of the people', the discourse actor favours the use of indefinite pronoun 'everybody' as active agent in the statement 'everybody is indoor listening [to] RADIOBIAFRA'. This usage makes the expression appear fallacious as it is practically impossible for all residents to have been listening to radio programmes, let alone the one(s) anchored on the station, Radiobiafra. The expression gives an impression that all residents of the state delight in listening to the programmes aired by the IPOB group. The highlighted expressions in this extract swell up the demonstration carried out by the Easterners more than it actually appears. More significantly, they are used to dominate the discourse, project the group's enactment of control over social activities, and thus consolidate their identity. This way of reinforcing identity underscores that identities are not necessarily 'fixed properties or finished products; rather they are constructed or deconstructed' (Georgakopoulou, 2002, cited in Chiluwa, 2014: 91).

The discursive (de)construction of group identity is equally played out through **image framing**. Framing, in media studies, is considered a tool for significant media effect (Scheufele & Tewksbury, 2007: 10; Scheufele, 1999: 105). It is how, in discourse, certain aspects of a situation are favoured and given salience while others are repressed (Entman, 1993: 55) or how discourse actors select, emphasise, and exclude certain ideas in communication (Gitlin 1980, cited in Molek-Kozakowska, 2016: 49) in order to slant the interpretation of social issues to favour their interest. In the excerpts below, discourse participants frame the image of their group/affiliate as good and situate oppositions as evil, through indicting frames, in such a way that the public can utilise 'them [the frames] as representative of the identit(ies)' of the opposition groups (Odebunmi & Oloyede, 2016: 286):

EX 3

We have further listened to defenseless and watery public clarifications concerning the massacre by the Anambra State Police Commissioner and his Public Relations Officer. In all these, we saw panics, contradictions, presidential and gubernatorial indictments, wickedness, callousness, parasitism, despotism, animalism, crookedness, cowardice, cannibalism, jihadism, ethnic cleansing, hate violence, and rabid falsehood in the said statements and roles of the [referenced] authorities into the massacre. …Mr. Solomon Arase who retires on 21st of June 2016 as Nigeria's worst IGP since 1999, with bucket-loads of blood of murdered innocent citizens on his head, is the principal architect of the ongoing massacre of the defenseless and unarmed Igbo Nationality activists via his riotous and murderous order of 1st of December 2015…

Labeling clearly non-violent and unarmed indigenous rights activists as armed without any concrete evidence till date, is murderous and genocidal. The effects of this can beastly be interpreted by killer police officers and uniform jihadists to mean license to kill or order from above to kill. All the State murders and proxy murders in Nigeria since December 2015 are expressly linked to President Muhammadu Buhari's reckless use of confrontational and combative words and issuance of war-like and genocidal orders to Nigeria's security forces against unarmed and nonviolent citizens (*The Nigerian Lawyer*, 2016).

EX 4

"The jihadists, in their quest to eliminate Christians in Plateau state and their thirst for blood, have succeeded in killing Christians and burning their houses," wrote Gyang… "They are right now attacking Rim, Bangai, Gwon, Wereng …." (*Morning Star News*, 2015)

EX 5

Inhabited almost entirely by ethnic Idoma farmers, the Fulani herdsmen from Nasarawa state, with mercenaries from Chad and Niger, razed several villages, destroying homes and church buildings in the predominantly Roman Catholic Agatu Local Government Area and forcing hundreds of Christians to flee (*Morning Star News*, 2014)

In excerpt 3, the discourse representative of the several coalition groups supporting the pro-Biafra activities is highly self-assertive of the role s/he claims the FGN, State governments and the Nigerian security operatives played in the killings of the demonstrators on May 30, 2016. The many negative lexicalisations such as 'contradictions', 'wickedness', 'callousness', 'despotism', 'animalism', 'crookedness', 'cannibalism', 'jihadism'; and negative collocations such as 'ethnic cleansing', 'hate violence', 'rabid falsehood', 'genocidal orders', 'killer police officers', 'uniform jihadists', 'State murders' and 'proxy murders' are an outright labelling of the Nigerian security operatives and the government as highly evil and malicious, while the positive collocations such as 'innocent citizens', 'defenseless…unarmed Igbo', 'clearly non-violent' and 'unarmed…rights activists' are a deliberate choice to project the identity of coalition of pro-Biafra groups as good. The pro-Biafra representative's report does not only label the security operatives as evil but also paints the identity for the then President Buhari and the Governor as evil leaders, claiming particularly that the President gave 'genocidal orders' to the security operatives to carry out 'ethnic cleansing' on the Igbo ethnic group.

In excerpts 4 and 5, by calling them 'jihadists' who are 'thirst[y] for blood' and who in 'their quest to eliminate Christians' have 'razed several villages' where the Christians reside, the actor frames the oppressing Muslim Fulani herdsmen as evil serial killers. In a bid to maintain a good identity for itself, it is also common for a group to present matters in ways that exonerate the parts it played in the crisis. As observed in the excerpts, such a group does so by being silent about its own action, and expected to be perceived as an easygoing and law-abiding group that is vulnerable to the attacks of the 'evil group'. This observation accentuates van Dijk's (2004: 41) assertion that where there is in-group

versus out-group polarization, in-group, in favour of its image, emphasises positive light about itself and represses any negative light, while emphasising negative things about the out-group and repressing positive things about it.

In a few instances, discourse actors further deploy transitivity in framing evil identity for oppositions and victim identity for self-group. Systemic Functional Grammar recognises transitivity as an ideational system of the clause that works out the types of process, the participants in the process and the circumstances associated with the process. The process is the verb of the clause that typifies the social action(s) in an event, and it is categorised into three: *material action process*, *mental action process* and *verbalised process* (Bloor & Bloor, 2004). In the next excerpts, however, we observe the material action processes and the circumstances surrounding them, which discourse participants extensively deploy for discursive purposes. The action process involves concrete, physical and dynamic actions that involve two agents of social actions: the Actor (the action performer) and the Recipient (i.e, Beneficiary or Affected Participants) unlike the mental and verbalised processes that respectively indicate the cognitive/sensual actions (e.g, 'like', 'look') and communicated actions as in 'talk' and 'chat' (Bloor & Bloor, ibid).

EX 6

Muslim Fulani herdsmen:

burn homes, church buildings.

killed a church pastor and more than 70 other Christians in Plateau state in the past month, sources said.

launched attacks on Monday (May 11) in Plateau state's Riyom LGA, a source told Morning Star News in a text message

"have succeeded in killing Christians and burning their houses," wrote Gyang…

"are right now attacking Rim, Bangai, Gwon, Wereng, Ringya and Sopp."

"...came to attack the village," he said.

"have continued with their invasion of Christian communities here," he said in a text message.

have long attacked settled Christian farmers in Plateau, Bauchi, Kaduna, Taraba and Adamawa states…

…attacked three villages in Nigeria's Plateau state in September, burning down a church building and killing at least 10 Christians.

EX 7

The Christians (in Riyom and Barkin Ladi LGAs):

have just been killed

were killed in Vat village, and 13 other Christians were slain in Zakupang, sources said.

have faced increasing attacks from Muslim militants and Muslim Fulani herdsmen in the past decade.

(*Morning Star News*, 2015)

EX 8

Kaduna and Plateau states <u>have had to endure</u> attacks from Muslim Fulani herdsmen....but recently Islamic groups <u>have been arming and accompanying</u> the herdsmen to incite conflicts with Christian farmers whose land the herdsmen covet to graze their cattle. (*Worthy News, 2016*)

The above excerpts reflect the clausal choices of the discourse producers. In excerpt 6, the herdsmen and Islamic groups are the Actors while the Christians, churches and Christian communities in Kaduna and Plateau States are the Affected Participants. In the examples given in excerpt 7, Christians are also the Affected Participants while the implied actors are (Muslim) Fulani herdsmen and gunmen. In the first example in excerpt 8, Kaduna and Plateau states are the Affected Participants, while the herdsmen are the (Implied) Actors, while in the second example of the same excerpt, Islamic groups are the Actors, the herdsmen Beneficiaries of the Islamic groups' action and Christian farmers, the Goal. The material processes found in the 3 excerpts are all violent options: 'burn', 'killed', 'launched attacks', 'have succeeded in killing', 'are (right now) attacking…', '...came to attack', 'have long attacked…', '…attacked three villages in Nigeria's Plateau state in September, burning down a church building and killing at least 10 Christians', 'have just been killed', 'were killed', 'have faced increasing attacks…', 'Kaduna and Plateau states have had to endure attacks…' and '…have been arming and accompanying (the herdsmen to incite conflicts)…' The fact that they occur in clauses where the 'Muslim Fulani gunmen/herdsmen' appeared all as Actors (and not once are they featured as Affected Participants) encodes the identity of the Fulani gunmen/herdsmen as a cruel, serial, determined, intolerant and belligerent group. Also, by not placing the Christian group as Actors of the violent material processes in the discourse, the discourse participants portray the group as peace-loving, non-violent but vulnerable and defenseless. The choice of exclusive use of violent material processes in the excerpts on the one hand, and selective inclusion of the two conflicting religious groups as agents of the processes on the other, show where the discourse actors belong in the ideological divide. Thus, discourse actors deploy transitivity to not only frame one group negatively and the other positively, but also to tilt the public towards believing that one side of the conflict deserves sympathies and the other, condemnation. It is a further indication that discourse actors employ the powerful role of the media to legitimise their own identities and to create that of the 'other' in ways that are particularly subjective (Chiluwa, 2011, cited in Chiluwa, 2014: 86).

Identity association/support is another discursive practice observed in identity construction discourse. It is the positioning, affinity or affiliation that actors discursively display or the 'interactionally relevant social relations [that speakers signal] through their participation in discourse' (Adegoju, 2016: 4). They deploy affective ways to play this associative role. One way of doing this is through the use of deictic reference or indexicals. Deixis is the system of pointing with linguistic indicators which are largely, all categories of pronouns, demonstrative adjectives, specific place/spatial and time adverbs (although not restricted to only these as there are other grammatical features that perform deictic functions as dictated largely by the context of the utterance in which they are found). They are features of language tied to the context of an utterance in such that decoding them would need the understanding of aspects of circumstances surrounding the utterance/discourse wherein they occur. In other words, they disclose important information (sometimes outside the text) that can aid the interpretation of the text.

EX 9

Many Nigerians have been killed, wounded or mutilated, kidnapped and deprived of everything: **their** loved ones, **their** land, **their** means of subsistence, **their** dignity and **their** rights. Many have not been able to return to **their** homes…

EX 10

I would like to assure **you** and all who suffer of **my closeness. Every day, I** remember **you** in **my prayers** and I repeat **here**, for your encouragement and comfort, the consoling words of the Lord Jesus, which must always resound in **our hearts**: "Peace I leave with you; my peace I give to you" (*Jn*14:27)…And so I wish here to express **my heartfelt thanks** to you, because in the midst of so many trials and sufferings the Church in Nigeria does not cease to witness to hospitality, mercy and forgiveness. How can **we** fail to remember the priests, religious men and women, missionaries and catechists who, despite untold sacrifices, never abandoned their flock, but remained at their service as good and faithful heralds of the Gospel? To them, most particularly, I would like to express **my solidarity**, and to say: do not grow tired of doing what is right!

EX 11

How can we fail to remember the priests, religious men and women, missionaries and catechists who, despite untold sacrifices, never abandoned their flock, but remained at their service as good and faithful heralds of the Gospel? To them, most particularly, I would like to express my solidarity, and to say: do not grow tired of doing what is right!

(*BellaNaija*, 2015)

Excerpts 9, 10 and 11 are from the news article written by Pope Francis condemning the Boko Haram's attacks in Nigeria. Though the several instances of possessive pronoun 'their' in excerpt 9 refer to the antecedent 'many Nigerians', they perform other discourse functions than just substituting the noun phrase 'many Nigerians'. The possessive pronoun 'their' provides a clear spatial and distant indication that the speaker (the Vatican) is not a Nigerian. Also, the repeated use of the pronoun in the text suggests that by closely keeping in touch with the situation in Nigeria, the Pope not only weighs 'everything' that is lost by 'many Nigerians' but also understands the gravity of their plight, and hence, largely sympathises with them.

In excerpt 10, there are clearly two different contexts of the use of person deixis, particularly, the 'I' and 'you' (written in bold). While the 'I' refers to the Pope, the 'you' represents the Nigerian Bishops/Christian communities, not the entire Nigerians even though he (the Pope) barely said this in the address. Furthermore, the repeated use of 'I' does not only refer to the Pope but is also reassuring his unflinching personal commitment (as shown with the time deixis, 'every day') to praying for Christian communities who are victims of Boko Haram attack in the Northern Nigeria. Hence, he personalises the concerns of his writing with the use of nominal phrases, 'my closeness', 'my prayers', 'my heartfelt thanks' and 'my solidarity' for Nigerian Christians. Personalisation like this seems to make Nigerian Christian readers feel more emotionally involved in the subject the Pope is addressing. However, unlike the boldened signifiers 'I' and 'you', the underlined signifiers *I* and *you* in 'Peace I leave with you; my peace I give to you' have different signifieds: the *I* rather refers to Jesus believing to be addressing the biblical Christians (not the Nigerian Christians) whom the *you* refers to in John14:27 (a section of the book of Christian religion). But the Pope appropriates these different significations into the context of Nigerian situation that he (the Pope) addresses, so that the *you* now specifically in the context of the text means only the Nigerian bishops or Christians and the I, the Pope who has borrowed the Jesus' statement to address them. Also, the context suggests that the spatial deixis 'here' does not refer to the place where the Pope was (i.e., the Vatican City) when writing the letter; rather it refers to the letter itself. In addition, the nominal phrase 'our hearts' and the first person 'we' signify a way by which the Pope (representing the entire catholic-hood) associates himself with Nigerian Christians having earlier in the text offered his sympathies to them in the event of their suffering at the hands of the religious extremist/terrorist, Boko Haram. In extract 11, the Vatican mainly 'express [his] solidarity' to 'the priests, religious men and women, missionaries and catechists' who are enduring attack from the insurgent group, Boko Haram in the Northern Nigeria. Though some parts of the letter subtly acknowledge that there were non-Christian victims too, this extract shows that the Vatican's sympathy is mainly with the Christians victims. He discursively

associates more with Nigerian Christians, than with the country as a whole; his address is not generalised to include many other Nigerian citizens who, notwithstanding their faiths, equally suffered from the untoward attacks.

In sensitive ER crisis situations, social actors or group usually strive to also defend their identity, protect their reputation and prevent others from construing their actions as being oppressive, even if they actually are. This discursive practice of identity defense is mainly carried out with the self-group vindication strategy. With this, actors attempt to tender reasons that could justify that their actions are right. They do this to exonerate themselves from public blame, especially where such actions can be perceived as outright victimisation of another group.

EX 12

"Instructively, troops of 82 Division Nigerian Army as the lead agency of the security agencies had to invoke the extant Rules of Engagement (ROE) to resort to self defence, protection of the strategic Niger Bridge, prevent re-enforcement of the pro-Biafra members apparently surging ahead from the far side of the strategic Niger Bridge at Onitsha. All these efforts were in order to de-escalate the palpable tension as well as ward off the apparent threats to lives and property in the general area…" [said in a statement signed by Colonel HA Gambo, Deputy Director of Army Public Relations, 82 Division of the Nigerian Army in Enugu].
(*Nairaland*, 2016)

EX 13

Why We Attacked Zakzaky, Other Shiite Members – Nigerian Army
The Nigerian Army on Saturday stated its reason for attacking members of the Islamic Movement of Nigeria. The Army had on Saturday said the group blocked the road and attempted to kill the Chief of Army Staff, Tukur Buratai, in Kaduna State.

In a statement on Sunday by its spokesperson, Sani Usman, the Army described the incident as 'most unfortunate' but blamed the sect for blocking roads meant for the public. "Yesterday's incident involving clashes between detachments of the Nigerian Army, accompanying the Chief of Army Staff Lieutenant General TY Buratai and followers of Sheikh Ibrahim El Zak-Zaky, suspected to be members of the Shiite Sect in Zaria, leading to loss of lives as a result of the Shiite group members' blocking roads and not allowing other passers-by to go about their lawful businesses and activities, was most unfortunate," Mr. Usman, a Colonel, said.

"…It is important to note that over the years this group has subjected ordinary citizens using public roads to untold hardship, delays, threats and disruption simply because they insist on using public space irrespective of inconvenience and hardship on other law abiding citizens and motorists. This cannot be tolerated and must stop!"
(*Nairaland*, 2015)

In excerpt 12, Nigerian Army personnel at different times absolved the military of any wrongdoing, particularly vindicating the Army's gruesome killings of members of pro-Biafra groups. They try to justify its murder action by

claiming that their actions are attempts to 'intervene' and secure the populace's lives and property. Their claim is that the military 'had at all-time adhered to rules of engagement in all of its operation'. Colonel H.A Gambo in his statement defends that the Army's actions were necessary to 'resort to self defence', 'protect…the strategic Niger Bridge', 'prevent re-enforcement of the pro-Biafra members' and prevent 'threats to lives and property'. In excerpt 13, after killing members of the Islamic Movement, Shiite, the Nigerian Army wards off the blame with the defence that the group 'blocked the road' and 'attempted to kill the Chief of Army Staff'. The spokesman of the Army equally vindicates his group by claiming that his group actions were done to protect the constitutional rights of 'other law-abiding citizens and motorists' 'using public roads' and save the people from the hands of the Shiite who 'subjected ordinary citizens…to untold hardship, delays, threats and disruption' by hijacking the roads.

6. Conclusion

The chapter has explored how actors discursively construct or deconstruct identity during ethno-religious matters. The study appropriated the three-dimensional model of CDA as theorised by Fairclough (1992), in understanding the construction of identity in the discourses of ethno-religious issues. There are discursive practices of interest consciousness, identity reinforcement, identity association/support and identity defense, which the discourse participants used to negotiate and construct self-group images, while they used framing to deconstruct other-group's identities. The analysis underscores the various role that linguistic devices such as metaphor, interdiscourse reference, dysphemism, lexicalisation, collocation, transitivity, deixis and nominal elements, as well as the discourse strategies of verbal attack and vindication of self-group played in giving effect to discursive construction and deconstruction of identity within the ambience of ER crisis discourses. Identity (de)constructions in ethno-religious discourses are also discovered to ideologically manifest. In other words, ideology is the basis of identity because social actors participate in discourse within the ideological divide; they do so by discursively establishing their identities in support of the ideology of the group to which they subscribe. This therefore is in tandem with Adegojus's (2016: 6) position that identity construction discourse is a base for the respective construction of knowledge formations and contestation of ideologies in the interests of group.

Away from reiterating the obvious impact of citizen media on social advocacy and civil action, the chapter has contributed to this domain by showing that crisis discourses on citizen media such as ethno-religious concerns, is vastly rich in language use, especially for identity representation, negotiation and or deconstruction as examined in the analysis. It is thus convincing that the avalanche of virtual freedom which citizen participants enjoy does not only spur their contribution to social interactions and civic engagement, but also accommodates ideological languages with which they take side in such conversations. Arguably however, altercations arising from identity construction/(re)negotiation and deconstruction divert attentions from the need to cohere towards tackling social crises, to goading disintegration that spells implication on Nigerian social and political co-existence.

Given the delimitation that this study only focused on ethno-religious concerns, future research could further investigate how group/individuals construct identities in discourses of other social concerns such as terrorism, domestic violence among other instances of security challenges. Imperatively, future studies might beam research lights on how crisis perpetrators/groups (such as Boko Haram, Indigenous People of Biafra, Hezbollah, among others)'s pre-and-post crisis deployment of language of threats and legitimation on online media spaces in consolidating their perpetrations.

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Appendix

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PARTICIPATORY APPROACH TO EXTENSION EDUCATION: A TOOL FOR ACHIEVING SUSTAINABILITY OF FOREST IN YOBE STATE, NIGERIA

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Abstract
Despite understanding the roles and contributions of forest extension workers in literature of management of forests in Sub-Saharan Africa, the forests in Northern Nigeria continue to deteriorate in size and composition, and literatures on suitable methods of forest extension and education is limited. This study aimed to examine the characteristics of the methods of forest extension and education in Yobe The objectives of the study therefore are to identify the characteristics of the methods of forest extension and education and assess the level of acceptability of the methods used in the transmission of information on sustainable forest management by forest extension and education workers in Yobe, Nigeria. Data were collected from 150 purposively selected respondents across the three randomly selected local government councils in Yobe, Nigeria. The data were analyzed using descriptive statistics, a general linear mixed model, and thematic analysis. The results identified five methods used in passing information on sustainable forest management to forests beneficiaries in the state namely the social (local leader) method, the community approach, the traditional group method, the social situation method, and the traditional individual approach. The social (local leader) method was the most acceptable method due to its characteristic reliability and fairness. The result from the modelling that regressed five predictor variables shows the social (local leaders) approach and the community approach as the predictors identified within the model that had the lowest Akaike's Information Criterion value of 157.8 and adjusted R^2 value of 26.8%. The adjusted R-squared value indicated that 73.2% of the people's opinions could not be explained by this model. This study highlight the ways to improve people's livelihood and identifies important indicators to enhance forest extension and education to achieve forests sustainability in Yobe. The results will provide information to policymakers in developing policy on the economic, social, and environmental benefits of forest. The study recommends policy measures aimed at inclusion of local leaders in the sustainable management of forests.

Keywords: Sustainability, Forest, Management, Livelihood improvement, Traditional leaders, Community, Participatory, Nigeria.

1 Introduction

The quest that led to the signing of international agreements and the development of laws and policies on the conservation of forests and biodiversity has called for adoptions of different strategies for achieving relevant Sustainable Development Goals (SDGs). Forest and Biodiversity are specified in several SDGs; for example, Goal 15 of the SDGs involves "protecting, restoration, and promoting sustainable use of terrestrial ecosystems, sustainable management of forests, combating desertification, halting, and reversing land degradation and stopping biodiversity loss" [1]. Similarly, SDG 12, addresses sustainable consumption and production patterns, SDG 13 underscores the importance of climate change and its impacts), and SDG 14 focuses on the sustainable use of the oceans and marine resources [1,2]. Forests and biodiversity were also discussed in Goals 1 and 2 as the preservation of a decent livelihood, the alleviation of poverty and hunger depend on Biosphere's health. Equally, maintaining good health and providing quality education (Goals 3 and 4) require harmony among humans and between humans and their environment [1,2]. Since the SDGs as international agreement promote global initiatives,. Its objectives can only be achieved through effective communication provided

through an appropriate channel acceptable by society. Therefore, to achieve SDGs, different stakeholders should be identified and included in the planning, decision and implementation processes. The greatest obstacle to an effective forest and wildlife management programme is a lack of clear public support for forest resources management [3]. It is therefore, a fundamental necessity for better public information to generate support for sustainability, which in turn requires competent staff to receive and transmit accurate information to the public. A conservation department without a strong and well-trained extension educator is hopelessly inefficient [3].

Collection of both timber and non-timber forest products (NTFPs) contributes significantly to poverty alleviation in Northern Nigeria by providing employment opportunities to the local population [4]; however, recent reports show that about 280,000 hectares of unreserved forests in Nigeria have been lost as a result of unsustainable practices [5,6]. Mohammed [7] observed the continuing loss of indigenous medicinal trees and biodiversity in Bade local government council of Yobe, Nigeria. Lack of access to new information on the sustainable management of forest resources by rural and urban people alike has affected the sustainability of some forest resources [4]. In the words of Ali [4], sustainability is the effective and efficient protection, preservation, and conservation for the continuing utilization and consumption of resources by the present and future generations. Sustainability ensures that the resources are used wisely so that the utilization contributes positively to the economic, social, and environmental development of the people and the society [8]. Elena [9] identified low awareness and lack of active involvement of local leaders among the factors that contribute to increasing pressure on forest trees. According to Bardy [3], traditional conservation laws are threatened and no longer adhered to, while the inclusion of local or tribal leaders in community development programme has decreased which has implications for sustainable forest management. Interestingly, new initiatives have been adopted to reduce and revert this threat in some countries. For example, in Ghana, an initiative was proposed for the preservation and application of traditional wisdom for sustainable development by creating regional centers that partner with local or communities' leaders as stakeholders to promote knowledge sharing and representation, and communicating new information on sustainable management [10].

Assessing the type, choice, and suitable approach to pass new information from forest department to the public is a key to achieving sustainability and a means for understanding the degree of success made in achieving sustainable development goals. Partnerships between educators, researchers, policymakers, tribal leaders, and situational leaders such as youth leaders within different local communities provide support for different developmental projects [11]. Wade [12] identified partnering practice between local leaders and the government as an effective and efficient approach to community development. Partnering is all about active participation aimed at establish groups that would co-create new compounds of shared knowledge and form standing committees to build strong bonds within stakeholder groups in addition to the establishment of commonly accepted solutions to problems related to the management of people and their environment. For example, In Southern Nigeria, the participatory approach has been used to resolve forests' related conflicts and issues effectively [13]. Similarly, the World Food Program (WFP) has supported different communities to established a "nursery, raise seedlings and manage community-development projects [14]. Ensuring the interests of all stakeholders are heard is similar to having a common understanding of principles [3,13]. Previous studies observed that particular approaches to forest extension and education suit particular communities [13,15] and that the factors that may influence the choice of a population to a specific approach to extension and education must be recognized due to cultural differences and beliefs ([9,16]

Despite the important contributions of the participatory approach to the efficient management of forest resources across the globe, studies on methods of forest extension and education for enhancing sustainable management of forests in Northern Nigeria remains scarce, and the few available studies mainly focused on the traditional Individual and group top-down method of passing information to communities [17]. Most importantly, the democratic system of government in Sub-Saharan Africa is often misused as politicians withdraw power from local leaders due to differences in political ideologies, thereby affecting the traditional communities' resource management and developmental issues [18,19]. The removal of the traditional leaders from their thrones and replacing them with their cronies for the purpose of achieving political interest has been found to impact on the traditional conservation laws negatively [3,13]. In some cases, political connections have led to non-adherence of the directives of the traditional leaders (e.g. emirs, chiefs and priests), which has since affected sustainable forest management and the conservation of biodiversity [3]. This study therefore, addressed the knowledge gaps by presenting a case study that examine the characteristics and acceptability levels of different methods of forest extension and education in Yobe state, Nigeria. The objectives of this study are therefore to: identify the methods used by extension workers in transmitting forest-related information, examine the characteristics of the methods, and determine the acceptability level of the methods of forest extension and education practiced in Yobe. The study is therefore guided by two research questions: how forest extension and education activities is delivered and which of the methods among others is more acceptable and suitable in Yobe state. We also tested two hypotheses to determine the factors contributing to the acceptance of specific approaches of forest extension and education:

1. H_A: Some factors that influence the suitability of methods of forest extension and education in Yobe state
2. H_0: No specific factors influencing the suitability of methods of forest extension and education in Yobe state

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2 Methodology

2.1 Location and area of the study

The study area is Yobe State in north-eastern Nigeria (Fig. 1A), Yobe state has 17 local government councils (Fig. 1B), a total land area of 4,660,900 hectares (ha) (46,609km^2), from which 386,710 ha represents areas covered by forests. Yobe State's vegetation is of two types. The southern part of Yobe is Sudan Savannah and is characterized by an annual average rainfall of 713mmHg. The northern part of Yobe state is a typical Sahel Savannah that has an annual average rainfall of 275mmHg, and a mean annual temperature of 35ºC to 39ºC [4]. Yobe state has a total population of 2,946,929 comprising 1,494,162 males and 1,452,769 females [20]. According to the National Bureau of Statistics report [21], the literacy level of adult male and female population in Yobe is 7.23%. As per livelihood source, the population in Yobe State relies on farming, animal husbandry, fishing, grocery, commercialization of NTFPs, and transport [4]. Nevertheless, the human poverty index (HPI) in Yobe is as high as 70%, with a high unemployment rate in the rural areas [4,14,22]. This study was specifically carried out in Damaturu, Potiskum, and Yusufari in Yobe state (Figure 1 B). The selection of the three study areas was purposive because they are the commercial centers of Yobe State, considered among the areas with a high number of forest reserves, and the presence of private plantations and agroforestry farms [4,14].
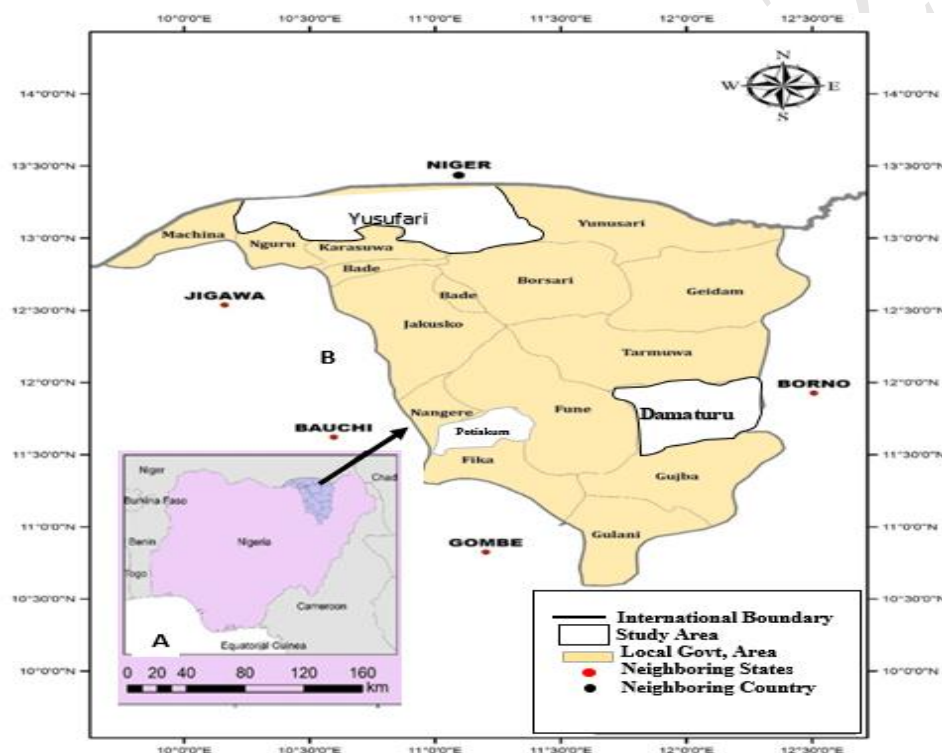
Fig. 1. Map of locations (A), and study areas (B).

2.2 Data collection

The data of the study was collected through both preliminary and actual surveys. The preliminary survey was carried out in January 2024, using nine key informants' interviews comprising one traditional leader, one religious leader, and forest zonal officers drawn from each of the three purposive selected local government councils. The results of the preliminary survey has led to the identification of the different groups of respondents recognized as major forest users or beneficiaries in Yobe (Table 1). The actual survey was carried out between March to Jul, 2024, using ten items of structured questionnaires that were distributed to purposively selected 150 respondents spread across the three randomly selected local government councils in Yobe state. The selection of only 150 respondents as a sample across five identified groups of forest users from the three local governments (n=30) was informed because of the qualitative nature of the survey questionnaires [15,23]. Additionally, the administration of the questionnaires by face-to-face interviews was due to the low literacy level of the population (forest users) in Yobe [24,25].

Table 1. Sample Size of Respondents and Location

Name of Study Areas	Name of Beneficiaries of Forest and Wildlife Resources					
	Fuelwood harvesters/Collectors	Fruits Gatherers/ Collectors	Hunters (Bush-meat Collectors) & Poachers	Agroforestry farmers & Plantation owners	Sculptors & Herbalist	Total
Damaturu	10	10	10	10	10	50
Potiskum	10	10	10	10	10	50
Yusufari	10	10	10	10	10	50
Total	**30**	**30**	**30**	**30**	**30**	**150**

2.3 Data Analysis

The data was analyzed using non-parametric statistical tools since the data did not meet the assumptions of parametric tests. Thus, descriptive statistics (percentage and mean), general linear mixed effect model (GLMM) analysis, and thematic analysis were used in analyzing the data of the study. Descriptive statistics was used to describe the quantitative data of the respondents' socio-demographic characteristics and the level of accessibility of forest extension and education methods.

2.3 General linear mixed model analysis (GLMM)

GenStat v12 used by Schall [26] was the main software used for GLMM analysis which helped to understand the effects of the predictor variables, i.e., forests extension and education methods) against the dependent variable (acceptability level). The selection of the predictor variables followed previous literature [3,24,27]. GLMM analysis therefore has helped to account for the random effects of different methods of forest extension and education in promoting sustainable forest management. Additionally, GLMM was adopted because of its inherent characteristics of accommodating data obtained from multiple sources, use of questionnaires with multiple responses/options' (e.g. binomial and multinomial response), and a study with many predictors variables [28.29,30].

2.4 Thematic Analysis

Thematic analysis was also used to analyze the qualitative data obtained on characteristics of the methods practiced to promote sustainable forest management in Yobe. Atlas ti8 (GmbH Berlin) was the software used in the analysis. we first collect the data, typed as word document, export to the software (data transcription), identify the codes (coding), and choose similar codes to develop the sub-themes and main theme (codes integration and development of main theme) following previous studies [8,31].

3 Results and Discussions

3.1 Socio-demographic profile of the respondents

Table 2 shows that the 150 respondents interviewed comprised 75% men and 25% women. The study further revealed that more than 76% of the total respondents were married and had an average household size of 13 persons. On the respondents' mean working experience, it was found to be 13 years. However, the least experienced categories of the respondents were the fuelwood collectors (one year), while fruit gatherers were the most experienced category of respondents (18 years), followed by Agroforestry farmers & Plantation owners and sculptors and herbalists, with 17 years working experiences each. Hunters and poachers have a mean working experience of 12 years (Table 2). The youngest group of respondents interviewed were the fuelwood collectors have a mean age of 22 years, On the other hand, the fruit gatherers were characterized by a mean age of 45.Siumilarly, the agroforestry farmers and plantation owners, as well as sculptors & herbalists have a mean age of 50 years. The hunters (bush-meat collectors) and poachers were the eldest among all respondents with a mean age of 56. In terms of educational level, most respondents across the study area lack formal education comprising 63% of fuelwood collectors and fruit collectors, 60% of hunters & poachers, 47% of agroforestry farmers and plantation owners, and 50% of sculptors and herbalists. Therefore, the sculptors and herbalists have the highest level of tertiary education, followed by agroforestry farmers & Plantation owners, then Hunters (bush-meat collectors) and poachers, who were followed by fruit gatherers. However, the fuelwood collectors generally have the lowest education status (Table 2). In terms of the employment status of the respondents, a majority (77%) of fruit collectors participate in forest fruit commercialization as part-time workers. Interestingly, 97% of the fruit gatherers, 87% of Hunters and poachers, 100% each of agroforestry farmers and plantation owners, and sculptors and herbalist work as

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full-time employees (Table 2). The result on the respondents' business ownership shows that all fuelwood harvesters, agroforestry farmers and plantation owners, and sculptors and herbalists (100%), and a majority of hunters and poachers (73%) were the sole owners of their businesses. 27% of the hunters and poachers were contracted, therefore recompensing of agreed bush meat to their sponsors (Table 2).

Table 2. Socio-Demographic Profile of the Respondents

Variable	Fuelwood Collectors	Fruits Collectors	Hunters & Poachers	Agroforestry farmers & Plantation owners	Sculptors and Herbalist	Mean
Gender (n) [%]						
Male	28[93]	30[100]	30[100]	27[90]	24[80]	NA
Female	2[7]	0[0]	0[0]	3[10]	6[20]	NA
Age (Yr)	22	45	56	50	50	41
Marital status						
Married	1[3]	30[100]	29[97]	27[90]	27[90]	NA
Single (n) [%]	29[97]	0[0]	1[3]	3[10]	3[10]	NA
Educ. Status (n) [%]						
Tertiary Educ.	0[0]	4[13.3]	1[3.3]	2[7]	8[27]	NA
Sec Educ.	7[23.3]	3[10]	4[13.3]	7[23.3]	4[13.3]	NA
Primary Educ.	4[13.3]	4[13.3]	7[23.3]	7[23.3]	3[10]	NA
Informal Educ.	19[63.3]	19[63.3]	18[60]	14[47]	15[50]	NA
Employment status (n) [%]						
Full-time	7[23]	29[97]	30[100]	30[100]	26[87]	NA
Part-time	23[77]	1[3]	0[0]	0[0]	4[13[	NA
Household size (person) (n)	1	14	13	13	13	11

Source: Authors Computed Field Data, 2024)
Yr (Year); **NA** (Not Applicable)

The results on the characteristics of the respondents indicated that men were the dominant beneficiaries of forest resources in the study area. For example, the fuelwood harvesters, who were mostly men, obtained their fuelwood from a long distance forests (forest reserves), while the few women did not travel long distances but relied on homestead forests such as communal forest areas, federal grazing reserves, buffer zones, and farmlands for domestic and commercial fuelwood. Moreover, fruit gathering and hunting businesses appeared to be gender-dependent in the studied area, as both were found to be dominantly carried out by men which confirm the previous study [4]. This may be explained by the fact that men are more associated with more physically intense and more risky livelihood activities in an area with high insecurity due to activities of armed bandits in some places in the study area. The result further show that women participate in less physical intense activities such as woodcraft business (wood curving or pestle and mortar construction) as well as participate in farming activity (agroforestry) in the study area.

As presented in Table 1, the profile of respondents except for sculptors and herbalists who attended higher level education (27%), all others groups including fuelwood harvesters, fruits gatherers, agroforestry farmers, and hunters and poachers were found to be least educated, as there were no or few persons that attended higher school. This may be explained by the occupation of the sculptors and herbalists that require innovative skills and/or experience acquired usually at lower and higher institutions of learning. According to UNESCO [32], the literacy rate in Yobe state, Nigeria, is 26.6%, and access to education for rural people is influenced by poverty and culture on the benefit of girl child education and gender equality that resulted in early marriage [4]. Moreover, a very low level of education associated with forest users in Yobe state is not surprising as the collection of NTFPs has been considered the primary job of less

privileged and uneducated people [4]. Furthermore, Table 1 shows that the age group of the fuelwood harvesters has deviated far from other groups, which shows that young men are more involved in physically intense activities, and the age group of the fruits gatherers (45 years), hunters and poachers (56 years), agroforestry farmers and plantation owners (50 years) and sculptors and herbalist (50 years) indicates that such occupation//activities are carried out by elderly people with higher experience received from parents or family business.

3.2 Practicing methods of forest extension and education and respondents' acceptability level of the methods

The qualitative data obtained were analyzed using thematic analysis that identified different methods practiced and experienced by the respondents (Table 3). The study identified five (5) methods experienced by the respondents across the three local government areas studied in Yobe. The traditional individual method (TIM) has 4 codes with 11 density count; the social (local leader) approach (SA) has 9 codes and 30 density counts; the community approach (CA) has 4 codes and 20 density counts; the social situational approach (SSA) has 5 codes with 13 density counts; and the traditional group method (TGM) possesses 8 codes and 29 density counts (Table 3),

Table 3. Codes identification, density counts and theme development of methods to Forest Extension and Education in Yobe State

Sub-themes Methods of forest Extension & Education	Contextual meaning	Building block of sub-theme (Code's Density count/scores)
Traditional Individual Method (TIM),	Refers to the method that involve extension worker meeting the farmer at home, in farm, in the forests, parks, plantation and discusses issues of mutual interests, given the client both information and pieces of advice. The approach believes in personal influence of extension worker in securing people's participation in extension activities	Lecture method (5) Tertiary Institutions training method (4) Individual method (2)
Social (local leader) approach (SA)	This method involves the use of local leaders (king, emirs district heads, wards heads, religious leaders, union leaders, occupational leaders, situational leaders) in transmission of information on sustainable management of forest and wildlife extension resources. The method brings about local support for extension activities. And often increase the coverage of extension teaching that can be done.	Tribal leaders approach (1) Local leaders approach (4) Union leaders approach (2) Occupational leaders approach (7) Situational leaders approach (1) Traditional leaders approach (10) Religious leaders approach (2) Chief's approach (1) Royal approach (2)
Community Approach (CA)	This method involves providing specialized and technical training to 1 or 2 people in a community who then promote a variety of appropriate technologies and provides technical services with occasional support from a supporting organization or institution or government agency and departments.	Education, Consultation and participation method (4) Village training method (5) NGOs training method (6) Inter-stakeholders discussion (3) Forest management training method (2)
Social Situational Approach (SSA)	It is the analysis of peculiarities of perception, motivation and reactions, and others. This involves the extension worker studying the people and their culture through books, periodicals, journals, newspapers, films, and slides or physically	Rural areas visitation method (2) Familiarization method (2) Research and accommodation method (5) Cultural method (2)

		Historical method (2)
	visiting the people before the actual extension activity. It provides the extension worker the ability to know the neighboring communities and their kindred's within a short period and know the kindred leaders and their names and able to conduct himself round and be able to organized clientele to participate in one activity or the other. (Elena *et al.,* 2018)	
Traditional Group Method (TGM)	This refers to bringing together two or more people to a particular spot to educate them on a subject matter of interest to them. Group methods take into account the inclination of the individual to respond to the pressures and opinions of groups in which he participates and to listen to the views of others before arriving at a decision about making changes in his farming operations.	General meetings (7) Group discussion (7) Exhibition (2) Tours and field trips (1) Demonstrations (5) Panel discussion (3) Brainstorming (3) Radio, television, internets, cinema/video, billboards and film strips/slides (1)

NOTE: A code refers to a word/phrase identified or used by the respondents to describe a method of forest extension and education, while 'density code scores/count' refers to the number of times a word/phrase was expressed by a respondent

3.3 Acceptability Levels of Methods of Forest Extension and Education

The results of the quantitative aspects of the questionnaire further revealed the acceptability level of the methods of the respondents. The social (local leader) approach is the most acceptable method by the respondents across the three local government councils followed by the traditional group method (TGM), which is then followed by the community approach. The fourth popular approach is the situational approach and the traditional individual method was found to be the fifth (Figure 3). Traditional leaders have been known to rise to different challenges of providing credible governance that contribute significantly to the development of society [27] On the other hand, the community approach has been employed to create an understanding of the roles and participate in raising and managing of seedlings as observed also in previous studies [16] while the choice of the situational approach show that the forest department and the forest users believe that forests and wildlife are surrounded by history. and for one to obtain and document historical data, one must rely on the personal-situational approach for a comprehensive study of the people and their culture because personality and his environment cannot be studied in isolation from each other [9]
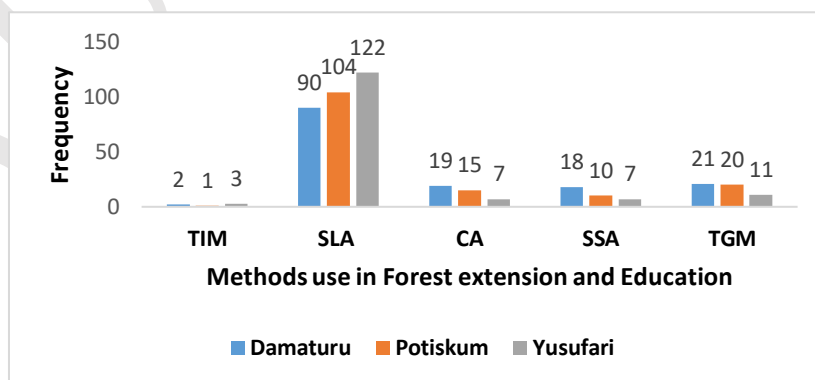
Fig. 2. Acceptability level of methods of forest extension and education for sustainable management of forest resources across the study areas of Yobe state

3.4 Characteristics of practicing methods of forest extension and education

Table 4 shows the characteristics of the methods adopted in transmitting information on sustainable forest management. For example, the traditional individual method (TIM) has the characteristics of timely delivery, and new knowledge. The social (local leader) approach (SA) was considered reliable, equity-inclined, and community development goal-oriented, the community approach (CA) is believed to add new knowledge and community development goal-oriented. The social situational approach (SSA) has been identified as people's cultural study approach, and respect for cultural norms-oriented goals, designed to achieve government conservational goals, and the traditional group method (TGM) is believed to add new Knowledge, leads to community development that provide direct benefit to the participants among others in the community (Table 4).

Table 4. Characteristics of the methods of Forest Extension and Education in Yobe state, Nigeria

S.N.	Approach to Forest Extension and Education	Characteristics
1.	Traditional Individual Method (TIM),	Timely + New Knowledge
2.	Social (local leader) Approach (SA)	Reliability + Equity + Community development Oriented
3.	Community Approach (CA)	Government Oriented Goal + New Knowledge + Community development Oriented
4.	Social Situational Approach (SSA)	Timely + New Knowledge +Equity + Community development Oriented + Respect + Government Oriented Goal
5.	Traditional Group Method (TGM)	Government Oriented Goal + New Knowledge + Community development Oriented + Group Benefit Driving

3.5 Effects size of the methods of forest extension and education for sustainable forest management in Yobe.

Table 5 shows the results of the levels of impact of the five (5) methods used in education and awareness creation on sustainable forest management in Yobe. Based on the effect size of each variable (Table 5), the degree of choice of predictor variables on acceptable methods of extension education was from the values of Akaike's Information Criterion (AIC). The AIC is an estimator of prediction error that provides information on the relative quality of the statistical model for a given data. The lower the value of the AIC of a model among others, the higher the quality of the information given by the model [26], while, the corresponding adjusted R^2 of each of the parsimonious models complements the IT approach. In other words, the adjusted R^2 value of the model with the lowest AIC (parsimonious model) represents the percentage acceptability contributions of the predictor variables enclosed in the parsimonious model [30].

Table 5. Effects size of five methods use in education and awareness creating on sustainable forest management in Yobe

S.N.	K: terms	Effect size	
		Adjusted R^2	AIC
1.	TIM	21.35	163.34
2.	**SA + CA**	**26.79**	**157.79**
3.	SSA + CA	24.25	160.62
4.	TIM + CA + SSA	26.93	158.55
5.	SSA + CA + TGM	24.25	160.62

Traditional Individual Method (TIM), Social (local leader) approach (SA), Community Approach (CA), Social Situational Approach (SSA), Traditional Group method (TGM)

4 Conclusion

This study used quantitative and qualitative data obtained from 150 respondents drawn from five (5) groups of forest users across three local government councils in Yobe State, Nigeria. The paper identified five (5) methods of forest extension and education practices in the course of transmitting information on sustainable forest management. The study observed the importance of local/traditional leaders in governance especially in promoting sustainable forest management, which was linked to the confidence reposed on them by the population that emanated from the leaders' characteristics reliability, equity, and fairness/justice toward their people. The paper provides an understanding of the characteristics, accessibility, and suitability of forest extension and education methods in Yobe State. Reliability and equity have greater influence among others that led to the choice of local leader method as the most acceptable and suitable approach to forest extension and education. The results also justify the importance of the roles the local leaders play in promoting sustainable forest management. Other variables such as timely (passing the information at the right time), new Knowledge, and respect to culture were found as important influencers in the choice of methods of forest extension education. Findings of this study show shows the need for the recognition and training of the local leaders, , as well as providing incentives for enhance sustainable forest management. There is a need for constitutional delegation of power of some aspect of forest management to traditional leaders. There is also the need of policy development on inclusion of local leaders in the sustainable management of forests. The results are significant information to policymakers in developing policy on the economic, social, and environmental benefits of forest (sustainable forest management). This study has also contributed to the empirical literature on the sustainability of forests in Yobe and Northern Nigeria. Our study focused only on the characteristics and acceptability of the practicing methods of forest extension and education in Yobe. Thus, future studies should focus on the adequacy, competence, and contribution of forest extension workers to sustainable forest management in Yobe State.

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RELATIONSHIP BETWEEN PRINCIPALS' SECURITY SAFETY TECHNIQUES AND EFFECTIVE MANAGEMENT OF POST BASIC SCHOOLS IN ADAMAWA STATE, NIGERIA

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Abstract

This study examined the relationship between principals' security safety techniques and effective management of Post Basic Schools in Adamawa State, Nigeria. Three research questions and four hypotheses guided the study. Correlational research design was adopted for this study. The population of this study is 6140. This population comprise of 340 principals' and 5800 teachers from the five education zones in Adamawa State. This sample for this study is 614. This sample size comprised 580 teachers' and 34 principals. Multi-stage sampling procedure was adopted for the study. The instrument used for data collection is a self-structured questionnaire titled "Principals' Security Safety Techniques Questionnaire (PSSTQ)" with a total of 15-items. PSSTQ yielded a reliability co-efficient of 0.80. Descriptive statistics of Mean and Standard Deviation were used in answering the three research questions raised for the study using real limits of numbers. Simple Linear Regression was used in testing hypotheses 1, 2 and 3, while ANOVA of Multiple Regression Analysis was used in testing hypothesis 4 at 0.05 level. The findings revealed that there is a significant relationship between the predictors (physical security management, human security management, technological security management) and effective management of Post Basic Schools, as evidenced by a significant F-statistic (F=5.996, p < .05). It can be concluded that technological security management technique makes the strongest unique contribution to explaining effective management of Post Basic Schools in Adamawa State, Nigeria. Based on the findings of the study, it was recommended among others: principals should endeavor to always use warning signs on perimeter fence, burglar proofing on windows and, protective lighting and other barriers (such as security gate across a passage) as these could further enhance effective school administration. Federal government, State Government and other non-governmental organizations should ensure principals deploy school personnel, parental participation and Rapid Armed Response (Policemen) in combating insecurity in their respective schools by providing them with the necessary manpower requirements and financial support.

Keywords: Principals' Security Safety Techniques, Physical Security Management Technique, Human Security Management Technique, Technological Security Management Technique, and Effective Management of Post Basic Schools.

1 Introduction

Learning requires a positive atmosphere where students feel not just physically safe, but emotionally and psychologically safe from all forms of dangers. Creating such environment means ensuring students safety throughout the entire school day by keeping them free from both physical, social or emotional threats within and outside the school environment. School security management is an integral and indispensable part of the entire school management system and must be properly handled to create a conducive school climate for effective pedagogy. [23] noted that students cannot learn if they do not feel safe and that a safe school environment is essential for students of all ages. For schools to be save, [10] noted that schools should have safety programmes and preventive strategies to be implemented by all stakeholders in the school. The finding is also supported by [40] who pointed out that to ensure security in the school compound, cameras should be placed throughout the school building which will allow school personnel to see and possibly video tape motion of anyone within the camera view in the school.

To continuously advance with effective security measures in schools, suggesting that the height of school fences and gates should be increased up to 1.5metre to provide effective security in the institutions. Besides, [13] opined that there should be installation guide signage at the gate, patrol of the school by community volunteers and the engagement of armed security guards in the schools. [36] suggested that school should go for Cisco physical security system which uses a Cisco IP video surveillance camera to dictate motions near the fence and automatically send alert to the school security

officers' mobile phone or pager. All these suggest to the effectiveness of the security measures identified in this study in providing sustainable security management measures in our secondary schools.

School security safety technique is the process of creating conducive and proper internal environment in the school [31]. School security safety technique according to [18], it refers to the steps taken to secure the learners both physically and psychologically by the use of variously assigned security awareness programmes and strategies. [20] asserted that school security management refers to ways of providing security technologies and strategies which can be used to mitigate formidable security threats in the school. It has to do with plans or measures taken to protect and manage school violence, reduce security risks, and ensure that the school environment is safe for learning. School security management is the plan for the protection that is given to the stakeholders within the school, learners, educators and managers from crime and accidents, by means of well-drawn policies which should be well managed [39]. The school is an organization that needs to have planned safety rules and regulations to protect its components so that the culture of learning and teaching is enhanced. According to [21], school security management refers to strategies and procedures required to co-ordinate the diverse activities of the school organization in order to achieve maximum safety. One of the important duties of the school manager is to ensure that safety programmes are implemented and that necessary steps are taken whenever situations arise which could be potentially dangerous [8].

Re-iterating, Ronoh (2018), safety and security measures are means of preventing crisis, and reacting to violations of existing rules that prohibits unruly behaviours which are likely to cause security and safety risks. Inconsonance to [35], [16], states that safety and security measures in schools involve obedience to] rules and regulations, reading labels on chemicals, laboratory equipment, wearing safety gadgets, having fire extinguisher in required places, observing road/path signs and highway codes, etc. Hence, a well-functioning school is not only a school that promotes teaching and learning, but also cares for safety and security of personnel and the available facilities. As opined by [14], school safety and security management measures/techniques are the strategies and procedures required to coordinate the diverse activities of the school, protect and manage school violence, reduce security risks and ensure that the school environment and the facilities are safe for teaching and learning. School principals embark on safety and security measures to protect students, staff and facilities in the event of dangers.

School security is the establishment and maintenance of protective measures that ensure a state of inviolability from hostile act or influences [29]. This is to say that security measures are to be reinforced to keep students, teachers, other workers and the environment free from harm and danger. Creating and maintaining secure environment needs clear understanding and management by all students, teachers and non-teaching staff. According to [29], it is essential that scholars and members of staff feel safe at school and it is for this reason that schools should have security plans in place which would be revised regularly.

Effective management of secondary schools refers to the control and co-ordination of man, material and financial resources of the school in order to attain the predetermined and stipulated aims, goals and objectives of secondary school education. In this regard, a well- managed school begins with advanced security and pedagogical planning by the head of the school and the teachers to ensure that teachers have adequate knowledge of their subjects and that security needs of students because without security, no meaningful learning can take place. The principal is expected to treat school security as a priority to ensure its adequacy in the environment. Managing school security is achieved through policies and programmes that embrace all stakeholders and demands that principals should be up-to-date with the modern security management practices that will help in making their schools safe and secure for teaching and learning. Despite the benefits of maintaining security in secondary schools in Nigeria and Adamawa State in particular, it appears that school principals, who are the chief executive officers of public secondary schools, are failing to apply adequate security management practices or measures in their schools. This claim is further evidenced by the prevalent incidence of bullying, gansterism and cultism by a group known as 'shila boys' which is prevalent in secondary schools in Adamawa State [44]. UNICEF further noted that principals must be concerned not only with the quality of instruction, but also with the maintenance of safety and security in the school. [29] asserted that the principal should endeavor to improve the school environment through the application of security management practices so that the teachers could feel confident, respected and safe. Managing school security is done by means of policies and programmes which will embrace all stakeholders.

Most of the incidents witnessed nowadays in schools indicate that schools are not safe and secure and that the perpetrators of violence in school come from within and outside schools [42]. The author stated that these perpetrators include students, their parents and mobs or individuals from the school communities and their targets are students, educators and principals, security guards and parents. Over the last decade, the consistent occurrence of insecurity, loss of life, kidnap and brings school security to the top of issues that need to be holistically studied and researched as to how to manage the situation from its current negative stride. [44] while commenting on the rate of insecurity in secondary schools noted that in the year 2021, there have been 20 attacks on schools in Nigeria, with 1,436 children abducted and

16 children dead. Some female and male students feel threatened as a result of rampant incidences of sexual abuse, rape, homosexual, bullying in schools and society. The case of bullying of a youngster, Sylvester Oromoni which happened in Dowen College, Lagos, which led to his death, the case of 10 years old girl of Christ-land College who was gang raped by her colleagues at their trip to Dubai, the case of homosexual reported at Deeper Life Secondary School in Oyu, Akwa Ibom state, just to mention a few [15]. The case of Teaching and learning will be unattainable when safety is amiss in the centre of community development [1]. Despite the challenging situation in the country on school security, schools still open their doors to students and staff knowing fully that the climate is riddled with all kinds of life-threatening mishaps; schools take measures to well manage staff and their students which is a great task added to their already demanding role of training future leaders. One of the important duties of the school principal is to ensure that safety programmes are implemented and that necessary steps are taken to keep the school safe whenever a potentially dangerous situation arises in the school [17].

School security management practice is a combination of strategies and procedures required to co-ordinate the diverse activities of the institution in order to achieve safety [45]. Hence, security management can be defined as the plan for the protection that is given to the stakeholders (learners, educators and managers) within the school from crime and accidents by means of well-drawn policies which should be well managed [41]. In the context of this study, school security management involves measures and procedures put in place to ensure the safety of lives and facilities. Furthermore, [45] highlighted four security management practices for ensuring school safety as follows: school security management procedures, physical security management practices, human security management practices and technological security management practices. When security procedures are in place, it then provides a platform on which physical security measures are put in place to curb security threats in these schools. This study was delimited to physical security management practices, human security management practices and technological security management practices. The school managers have to be at alert by putting adequate physical security measures in place to cope with the current wave of security threats in the country [1] stressed the need to continuously advance with effective school security measures, and suggested that the heights of school fences and gates should be increased up to 1.5 meters. [13], opined that there should be installation of guide signage at the gate, patrol of the school personnel, community volunteers and armed security guards in the schools.

Physical security management practices are implemented in schools to ensure the safety of lives and property. When physical security practices are correctly and effectively implemented a school principal, maximum protection will be guaranteed. Physical security measures can be divided into three categories consisting of the outside perimeter measures, inner middle perimeter measures and the internal measures [2]. Examples of physical security measures are school fences, school locks and keys, burglar-proof, CCTV, radio, intercom, telephone and intercom systems. The outside perimeter measures are found outside of the school building normally the perimeter (first line of defence) of the premises such as signs, fences and other barriers (barricades), lighting, alarms and patrols. The inner middle ring (inside) are the security measures used within the boundaries of the facility and can include fences and other barriers (walls), alarms, lighting (often with motion detecting capabilities), Close Circuit Television (CCTV) cameras, warning signs, doors, locks, burglar proofing on windows, security staff and access control systems. Lastly, the internal physical security measures are found within buildings and include alarms, CCTV cameras, turnstiles, windows and door bars, locks, safes, vaults, protective lighting and other barriers (such as security gate across a passage [14]. These physical security tools are very essential to maintaining security in the school; however, they cannot function without human beings. Hence, the need for human security management practices [32].

The human security management practices are aspects of security management that deals with the use of human beings in preventing and combating security threats [45]. According to [7], using human beings in security systems is often either overlooked or neglected completely. Despite the facts that human's plays vital roles in security. It is usually the humans that make the decision to take action and decide on what action to take during a crisis or emergency [7]. Most technological practices will not be able to function successfully without a human component. For example, if an alarm is triggered at a school, a policeman or security guard will have to respond to the alarm in order for the technological aid to work effectively and for the intruder to be apprehended. Some of the human components in security could include guards, community and/or parental participation, school personnel, security officers, private security company personnel on contract who might also offer a rapid armed response service or police officers. As much as the human components of security are important, it is believed that the application of technology will help to improve their ability to ensure adequate security in the school. [45] opined that technological security management practices, as adjunct to physical security management, can be excellent tools and make great contributions to the safety of scholars and staff as well as reducing violence in schools.

Technological security management practices are aspects of security management that deals with the application of technological tools and equipment in preventing and combating insecurity [22]. Technological security management practices should, however, be correctly applied within the school environment and maintained after the installation,

otherwise they will not be effective. Security technologies that can be implemented within a school include closed circuit television (CCTV) systems, including the videoing and storing of video surveillance footage whether analogue or digital; intruder alarms; metal detectors or hand- held detectors; x-ray machines and/or card reader systems [29]. According to the authors, these technologies can assist a school by providing information that would not otherwise be available, can free- up manpower and can, in-the-long-run, be cost- effective for a school.

[32], Pointed out that some of the safety and security measures in personnel management (staff and student) could include guards, community or parental participation, security officers, private security personnel on contract who might also offer a rapid armed response service or police officer, town vigilante group. There have been hues and cries over the safety and security of students, staff and facilities in Nigerian secondary schools [38]. [27] stressed that secondary school students in Nigeria are often very much in danger of being harmed and the perception can lead to withdrawal from school. In the same vein, [28] lamented on the adverse effect of insecurity on the students, parents and the community. On the issue of safety of use of school facilities, [46], observed that many educational facilities in Nigerian secondary schools recently are sources of hazards (dilapidated structures, classrooms, furniture's and bushy environment) to mention but a few. [47], stated that a large percentage of secondary schools in Nigeria are unsafe, there are no fire extinguishers, poor water supply and there is general lack of knowledge about safety and security measures among students and staff.

Despite the importance of school safety, there seems to be an upsurge of violence arising quite rapidly in schools. It seems that a new wave of mayhem in society has not spared the secondary schools. It is expected that secondary school principals and members of the school management should be at alert all the time to prevent occurrence and the acts of hooliganism to avoid blames for professional negligence. In some schools, students resort to senseless destruction, burning, maiming, raping or even killing those teachers they think are harsh on them [29]. Ojo reported that some students go to school with jack knifes, battle axes and even locally made guns to threaten and bully fellow students. These problems not only endanger students and teachers but they also prevent teachers from concentrating on teaching and students from concentrating on learning.

There has also been an increased influx of cult groups into secondary schools in Nigeria including Adamawa State resulting to high security threats. This unfortunate situation has increased the call for adoption of security management measures which may curb the menace of insecurity and make secondary schools safe for teaching and learning. Security management practices like school security management procedures, physical security management practices, human security management practices, and technological security management practices have been proffered as effective in curbing school security threats. However, the level of adoption of these security management practices by secondary school principals " in Adamawa State is not clearly known. Thus, what are the practices applied by principals in Adamawa State to protect immediate school members and her host community from security threats? Therefore, the problem of this study put in question form is: what is the relationship between principals' security safety techniques and effective management of Post Basic Schools in Adamawa State, Nigeria?

2 Objective of the Study

This study examined the relationship between principals' security safety techniques and effective management of Post Basic Schools in Adamawa State, Nigeria. Specifically, the study examined the relationship between principals' security safety techniques of;
1. Physical security management technique and effective management of Post Basic Schools in Adamawa State, Nigeria.
2. Human security management technique and effective management of Post Basic Schools in Adamawa State, Nigeria.
3. Technological security management technique and effective management of Post Basic Schools in Adamawa State, Nigeria.

3 Research Questions

The following research questions were raised to guide the study:
1. What is the level of physical security management technique in Post Basic Schools in Adamawa State, Nigeria?
2. What is the level of human security management technique in Post Basic Schools in Adamawa State, Nigeria?
3. What is the level of technological security management technique in Post Basic Schools in Adamawa State, Nigeria?

4 Statement of Hypotheses

The following null hypotheses were formulated to guide the study and were tested at 0.05 Alpha level of significance:

1. There is no significant relationship between physical security management technique and effective management of Post Basic Schools in Adamawa State, Nigeria.
2. There is no significant relationship between human security management technique and effective management of Post Basic Schools in Adamawa State, Nigeria.
3. There is no significant relationship between technological security management technique and effective management of Post Basic Schools in Adamawa State, Nigeria.
4. There is no significant relationship between principals' security safety techniques (physical security management, human security management, technological security management) and effective management of Post Basic Schools in Adamawa State, Nigeria.

5 Methodology

Correlational research design was adopted for this study. The study area is Adamawa State, Nigeria. The population of this study is 6140. This population comprise of 340 principals' and 5800 teachers from the five education zones in Adamawa State [34]. Based on the five education zones in Adamawa State, the population is further broken down into; Ganye (1059 principals and teachers), Numan (1236 principals and teachers), Gombi (1178 principals and teachers), Mubi (1291 principals and teachers), and Yola (1376 principals and teachers) respectively. Principals constitute the respondents of this study because of the fact that they are at in the best position to give detailed information on how security safety techniques affect the management of their respective schools. Also, principals constitute the respondents of this study because as instructional heads, they are in the best position to give detailed information on how security safety techniques affect their daily classroom assigned responsibilities.

This sample for this study is 614. This according to [9] who stated that 10% is satisfactory in every population of 5000 and above. And using this method upholds that each member of the population of the study has equal chances of being selected. This sample size comprised 580 teachers' and 34 principals. Multi-stage sampling procedure was adopted for the study. The reason for using multi-stage sampling is because different sampling techniques were applied at different stages in selecting the Post Basic School principals and teachers [9].

Firstly, schools were stratified into the five already existing educational zones in the State which include; Mubi, Ganye, Gombi, Numan and Yola zones. Simple random sampling technique (hat and draw to be specific) was used in sampling 34 Post Basic Schools from the five educational zones in the state, based on the assertion by [9], that in using simple random sampling technique, each element of the population has equal and independent chance of being included in the sample. To Creswell, simple random sampling does not only give each element in the population an equal chance of being included in the sample, but also makes the selection of every possible combination of the desired number of respondents equal. A total number of 34 Post Basic Schools were selected across the five Education Zones of; Yola, Numan, Ganye, Gombi and Mubi in Adamawa State.

Secondly, proportionate stratified random sampling technique was used in selecting the respective numbers of teachers per sampled school across the five Education Zones in the following order; Yola=127, Numan=117, Ganye=103, Gombi=111 and Mubi=122, totaling 580. Proportional stratified random sampling involves taking random samples from stratified groups, in proportion to the population. This is done to avoid every element of bias that could arise due to the researcher's familiarization with any given Education Zone. Proportionate stratified random sampling technique was used because the researchers were interested in taking random samples from stratified groups, in proportion to the population. The use of this sampling technique is justified because stratification gives a smaller error in estimation and greater precision than the simple random sampling method: the greater the differences among the strata, the greater the gain in precision.

Thirdly, simple random sampling technique was further used in selecting the 580 teachers across the five Education Zones respectively. The choice of this sampling technique is to give each of the 580 teachers' equal opportunity of being included in the study. In this study, principals and teachers stand in a better position of providing reliable and realistic information needed for the study. Especially as it relates to principals' security safety techniques (physical security management, human security management, technological security management) and effective management of Post Basic Schools in Adamawa State, Nigeria. Fourthly, purposive sampling technique was used in selecting principals from each of the 34 selected Post Basic Schools in the five Education Zones of; Yola, Numan, Ganye, Gombi and Mubi in Adamawa State

The instrument used for data collection is a self-structured questionnaire titled "Principals' Security Safety Techniques Questionnaire (PSSTQ)" with a total of 15-items. The items were structured on a five-point rating scale of VHL=Very High Level (4), HL=High Level (3), ML=Moderate Level (3), LL=Low Level (2) and VLL= Very Low Level. To ensure the validity of the instrument, the instrument was submitted to three senior lecturers from the Department of Physical Sciences Education, Faculty of Education, Modibbo Adama University, Yola for face and content validation. Data were collated and analyzed for reliability using Cronbach Alpha Statistic. Cronbach Alpha Statistics was used because it helped the researchers to determine the internal consistency of items of the instrument. The reliability co-efficient of (PSSTQ) yielded 0.80. This total reliability coefficient of 0.80 was considered high enough and reliable to be used for the study.

Six hundred and fourteen (614) copies of the instrument were administered to the respondents by the researchers with the aid of ten well-briefed research assistants who are conversant with the study area. The direct delivery approach was to use to enable the researchers and research assistants to thoroughly explain the purpose of the study to the respondents and also, to ensure all completed questionnaire copies are retrieved on the spot. Descriptive statistics of Mean and Standard Deviation were used in answering the three research questions raised for the study using real limits of numbers. Simple Linear Regression was used in testing hypotheses 1, 2 and 3, while ANOVA of Multiple Regression Analysis was used in testing hypothesis 4 at 0.05 level. The decision rule was that, if the p-value is less than the significance level ($\alpha = 0.05$), the null hypothesis would be rejected and alternative hypothesis accepted.

6 Results

Three research questions were raised and answer using descriptive statistics of mean and standard deviation. Three hypotheses were also formulated and tested at 0.05 level of significance using Simple Linear Regression and Multiple Regression Analysis.

6.1 Research Question One

What is the level of physical security management technique in Post Basic Schools in Adamawa State, Nigeria?
To answer this research question, responses on the level of physical security management technique in Post Basic Schools in Adamawa State, Nigeria were collected and analyzed as shown in Table 1.

Table 1 Mean and Standard Deviation of Level of physical security management technique in Post Basic Schools in Adamawa State, Nigeria

S/N	Items n=580	Mean	S. D	Remark
1	Warning signs on perimeter fence	4.79	1.05	HL
2	Burglar proofing on windows	4.58	0.99	HL
3	Alarms on doors	4.36	0.92	HL
4	Protective lighting and other barriers (such as security gate across a passage	4.56	0.94	VHL
5	Turnstile configured to enforce one-way human traffic in schools	3.99	0.86	HL
	Average Mean	**4.46**	**0.95**	**HL**

The average mean and standard deviation of physical security management in Post Basic Schools in Adamawa State, Nigeria are shown in Table 1. In **Post Basic Schools in Adamawa State**, a high level of physical security management technique indicated by an average mean score of 4.46 and standard deviation value of 0.95. This implies that principals use warning signs on perimeter fence, burglar proofing on windows and, protective lighting and other barriers (such as security gate across a passage) to a high level.

6.2 Research Question Two

What is the level of human security management technique in Post Basic Schools in Adamawa State, Nigeria?
To answer this research question, responses on the level of human security management technique in Post Basic Schools in Adamawa State, Nigeria were collected and analyzed as shown in Table 2

Table 2 Mean and Standard Deviation of level of human security management in Post Basic Schools in Adamawa State, Nigeria

S/N	Items n=580	Mean	S. D	Remark
1	Private security guard	4.64	1.02	HL
2	Rapid Armed Response (Policemen)	4.77	1.06	VHL
3	Parental participation	4.79	1.08	VHL
4	School personnel	4.80	1.09	VHL

5	Community participation (local vigilante group)	4.68	1.03	VHL
	Average Mean	**4.74**	**1.06**	**VHL**

The mean and standard deviation of the level of human security management in Post Basic Schools in Adamawa State, Nigeria are shown in Table 2. A high level of human security management technique in Post Basic Schools in Adamawa State, Nigeria is indicated by an average mean score of 4.74 and standard deviation value of 1.06. This implies that to a very high level, Post Basic School principals deploy school personnel, parental participation and Rapid Armed Response (Policemen) in combating insecurity in their respective schools.

6.3 Research Question Three

What is the level of technological security management technique in Post Basic Schools in Adamawa State, Nigeria?
To answer this research question, responses on the level of technological security management technique in Post Basic Schools in Adamawa State, Nigeria were collected and analyzed as shown in Table 3.

Table 3 Mean and Standard Deviation of level of technological security management technique in Post Basic Schools in Adamawa State, Nigeria

S/N	Items n=580	Mean	S. D	Remark
1	Closed Circuit Television (CCTV) systems, including the videoing and storing of video surveillance footage whether analogue or digital	4.67	1.00	VHL
2	Intruder alarms	4.39	0.98	VHL
3	Metal detectors	4.89	1.09	VHL
4	Hand- held detectors	4.90	1.12	VHL
5	X-ray Machines and/or card reader systems	4.28	0.93	VHL
	Average Mean	**4.63**	**1.02**	**VHL**

Result of analysis in Table 3 shows the mean and standard deviation of level of technological security management technique in Post Basic Schools in Adamawa State, Nigeria. An average mean of 4.63 and standard deviation of 1.02 shows very high level of technological security management technique in Post Basic Schools in Adamawa State, Nigeria. This implies that Post Basic School principals use; Hand-held detectors, Metal detectors and Closed-Circuit Television (CCTV) systems, including the videoing and storing of video surveillance footage whether analogue or digital to a very high level.

7 Hypotheses Testing

7.1 H_{01}: There is no significant relationship between physical security management technique effective management of Post Basic Schools in Adamawa State, Nigeria.

Table 4a Result of Regression Analysis of Significant relationship between physical security management technique effective management of Post Basic Schools in Adamawa State, Nigeria.

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	9.269	1	9.269	7.866	.008[b]
	Residual	41.613	32	1.178		
	Total	50.882	33			

a. Dependent Variable: Effective management of Post Basic Schools
b. Predictors: (Constant), Physical security management technique

Table 4a presents the results of a regression analysis examining the relationship between physical security management and effective management of Post Basic Schools in Adamawa State, Nigeria. The table shows that the regression model is statistically significant ($F(1, 33) = 7.866$, $p < .05$), indicating that there is a significant relationship between physical security management and effective management of Post Basic Schools in Adamawa State, Nigeria.

Table 4b: Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.449[a]	.196	.472	1.02469

a. Predictors: (Constant), Physical security management technique

Table 4b provides a summary of the regression model, showing that the model has a moderate effect size (R = .449), meaning that there is moderate relationship between physical security management and effective management of Post Basic Schools in Adamawa State, Nigeria. The predictors in the model account for a significant proportion of the variance in effective management of Post Basic Schools in Adamawa State (R^2 = .197). The adjusted R^2 value suggests that approximately 47.2% of the variance in effective management of Post Basic Schools in Adamawa State can be explained by principals' physical security management technique.

Table 4c: Coefficients of Beta

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.083	.590		3.452	.001
	Physical security management technique	.421	.150	.449	2.806	.008

a. Dependent Variable: Effective management of Post Basic Schools

Table 4c displays the coefficients for the predictors in the regression model. The standardized coefficient (Beta) for physical security management technique is .449, indicating a moderate positive relationship with effective management of Post Basic Schools. The t-value of 2.806 suggests that the relationship is statistically significant (p = .008).

7.2 H_{02}: There is no significant relationship between human security management and effective management of Post Basic Schools in Adamawa State, Nigeria.

Table 5a: Results of Regression Analysis of Significant relationship between human security management technique and effective management of Post Basic Schools in Adamawa State, Nigeria

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	9.885	1	9.885	9.460	.004[b]
	Residual	35.897	32	1.045		
	Total	45.692	33			

a. Dependent Variable: Effective management of Post Basic Schools
b. Predictors: (Constant), Human security management technique

Table 5a illustrates the results of a regression analysis examining the relationship between human security management technique and effective management of Post Basic Schools in Adamawa State, Nigeria. The table indicates that the regression model is statistically significant (F(1, 33) = 9.460, p < .05), suggesting a significant relationship between principals' human security management technique and effective management of Post Basic Schools in Adamawa State, Nigeria.

Table 5b: Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.476[a]	.228	.504	1.00480

a. Predictors: (Constant), Human security management technique

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Table 5b provides a summary of the regression model, indicating that the model has a moderate effect size (R = .476), meaning that there is moderate relationship between principals' human security management technique and effective management of Post Basic Schools in Adamawa State, Nigeria. The predictors included in the model account for a considerable proportion of the variance in effective management of Post Basic Schools in Adamawa State, Nigeria (R^2 = .228). The adjusted R^2 value suggests that approximately 50.4% of the variance in effective management of Post Basic Schools in Adamawa State, Nigeria can be explained by principals' human security management technique

Table 5c: Coefficients of Beta

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.717	.655		2.621	.013
	Human security management technique	.551	.179	.476	3.078	.004

a. Dependent Variable: Effective Management of Post Basic Schools

In Table 5c, the coefficients for the predictors in the regression model are presented. The standardized coefficient (Beta) for human security management technique is .476, indicating a moderate positive relationship with effective management of Post Basic Schools. The t-value of 3.076 suggests that the relationship is statistically significant (p = .004).

7.3 H₀₃: There is no significant relationship between technological security management technique and effective management of Post Basic Schools in Adamawa State, Nigeria.

Table 6a: Results of Regression Analysis of significant relationship between technological security management technique and effective management of Post Basic Schools in Adamawa State, Nigeria

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	9.998	1	9.998	9.860	.004[b]
	Residual	33.995	32	1.014		
	Total	43.993	33			

a. Dependent Variable: Effective Management of Post Basic Schools

b. Predictors: (Constant), Technological Security Management Technique

Table 6a shows the results of the regression analysis testing the relationship between technological security management technique and effective management of Post Basic Schools in Adamawa State, Nigeria. The regression model is statistically significant, $F(1, 33) = 9.860$, p < .05, indicating that there is a significant relationship between technological security management technique and effective management of Post Basic Schools in Adamawa State, Nigeria.

Table 6b: Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.488[a]	.246	.318	.99993

a. Predictors: (Constant), Technological Security Management Technique

In Table 6b, the model summary shows that the correlation coefficient (R) between technological security management technique and effective management of Post Basic Schools in Adamawa State, Nigeria is .488, indicating a moderate positive relationship. The coefficient of determination (R Square) is .246, indicating that 31.8% of the variance in effective management of Post Basic Schools can be explained by principals' technological security management

technique. The adjusted R Square is .318, suggesting that when considering the number of predictors in the model, the explanatory power decreases slightly.

Table 6c: Coefficients of Beta

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.881	.592		3.175	.003
	Technological security management technique	.524	.167	.488	3.137	.006

a. Dependent Variable: Teachers' job performance

Table 6c presents the coefficients for the predictors in the model. The unstandardized coefficient (B) for technological security management technique is .524, indicating that for every one-unit increase in technological security management technique, there is a corresponding increase of .524 units in effective management of Post Basic Schools. The standardized coefficient (Beta) is .488, indicating the strength and direction of the relationship between technological security management technique and effective management of Post Basic Schools in Adamawa State, Nigeria. The t-value is 3.137, which is statistically significant at $p < .05$, providing further support for the significant relationship found in the regression analysis.

7.4 H_{04}: There is no significant relationship between principals' security safety techniques (physical security management, human security management, technological security management) and effective management of Post Basic Schools in Adamawa State, Nigeria.

Table 7a: Results of Regression Analysis of Significant relationship between principals' security safety techniques (physical security management, human security management, technological security management) and effective management of Post Basic Schools in Adamawa State, Nigeria

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	21.648	3	4.329	5.996	.001[b]
	Residual	20.204	31	.722		
	Total	41.852	33			

a. Dependent Variable: Effective Management of Post Basic Schools

b. Predictors: (Constant), Physical security management, human security management, technological security management

Table 7a presents the results of a regression analysis examining the relationship between various security safety techniques possessed by principals and effective management of Post Basic Schools in Adamawa State. The regression model indicates that there is a significant relationship between the predictors (physical security management, human security management, technological security management) and effective management of Post Basic Schools, as evidenced by a significant F-statistic (F=5.996, $p < .05$). This suggests that at least one of the predictor variables has a non-zero effect on effective management of Post Basic Schools.

Table 13b: Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.712[a]	.502	.432	.84967

a. Predictors: (Constant), physical security management, human security management, technological security management.

In Table 7b, the model summary provides additional insights into the regression model's performance. The r – value of 0.712 indicate that there is strong relationship between the predictor variables (physical security management, human security management, technological security management) and effective management of Post Basic Schools in Adamawa State, Nigeria. The R-square value of .502 indicates that approximately 50.2% of the variance in effective management of Post Basic Schools in Adamawa State, Nigeria can be explained by the combined effect of the predictors. The adjusted R-square, which accounts for the number of predictors in the model, is .432, suggesting that the model's explanatory power decreases slightly when considering the complexity of the predictors.

Table 7c: Coefficients of Beta

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.267	.778		-.343	.734
	Physical security management technique	-.198	.240	.309	.876	.418
	Human security management technique	.167	.391	.195	.426	.674
	Technological security management technique	.410	.146	.480	2.803	.079

a. Dependent Variable: Effective Management of Post Basic Schools

Table 7c displays the coefficients from a multiple regression analysis, revealing how each variable in the model contributes to predicting effective management of Post Basic Schools. The analysis shows that physical security management technique has a beta value of 0.309, indicating that it explains 30.9% of the variance in effective management of Post Basic Schools, with a t-value of 0.876 and a p-value of .418. Similarly, human security management technique has a beta value of 0.195, explaining 19.5% of the variance in effective management of Post Basic Schools, with a t-value of 0.426 and a p-value of .674. On the other hand, technological security management technique has a beta value of 0.480, explaining 48.0% of the variance in effective management of Post Basic Schools, with a t-value of 2.803 and a p-value of .079.

It can be concluded that technological security management technique makes the strongest unique contribution to explaining effective management of Post Basic Schools in Adamawa State, Nigeria when controlling for the variance explained by all other variables in the model, as it has the largest beta coefficient of .480. In contrast, human security management technique makes a comparatively smaller unique contribution, with a beta value of .195.

8 Summary of Major Findings

The following are the findings of the study:
1. Physical security management and effective management of Post Basic Schools in Adamawa State, Nigeria is statistically significant at $F_{(1, 33)} = 7.866$, $p < .05$.
2. Human security management technique and effective management of Post Basic Schools in Adamawa State, Nigeria is statistically significant at $F_{(1, 33)} = 9.460$, $p < .05$.
3. The results revealed that technological security management technique and effective management of Post Basic Schools in Adamawa State, Nigeria statistically significant at $F_{(1, 33)} = 9.860$, $p < .05$.
4. The regression model indicates that there is a significant relationship between the predictors (physical security management, human security management, technological security management) and effective management of Post Basic Schools, as evidenced by a significant F-statistic (F=5.996, $p < .05$). This suggests that at least one of the predictor variables has a non-zero effect on effective management of Post Basic Schools. It can be concluded that technological security management technique makes the strongest unique contribution to explaining effective management of Post Basic Schools in Adamawa State, Nigeria when controlling for the variance explained by all other variables in the model, as it has the largest beta coefficient of .480. In contrast,

human security management technique makes a comparatively smaller unique contribution, with a beta value of .195.

9 Discussions of Findings

The finding of this study revealed that physical security management and effective management of Post Basic Schools in Adamawa State, Nigeria is statistically significant at $F_{(1, 33)} = 7.866$, $p < .05$). The major findings were that principals use warning signs on perimeter fence, burglar proofing on windows and, protective lighting and other barriers (such as security gate across a passage) to a high level. This finding agrees with the findings of [1] whose findings revealed that there was a significant relationship between physical school security measures and staff job performance in secondary schools in Ilorin metropolis which means that if the school has enough physical and technical security measures to prevent student problem behaviours in secondary school, it will lead to effective performance of school staff positively. This finding corroborate with that of [29] whose findings indicated that physical security measures were adopted by principals in public secondary schools in Anambra State. The finding corroborate with that of [4] whose study revealed that safety and security measures are adopted by principals for staff and students management of public secondary schools in Imo State, Nigeria. [4] further revealed that safety and security measures adopted by principals for staff and students' management include the issuance of identity cards to staff and students to distinguish them from intruders; formulation of strict school safety rules and regulations; orientating staff and students on security tops to safeguard their life, stationing of security guard at school gate, enlightenment of staff and students on regular safety and security updates among others. The finding was in congruent with [30] who revealed that principals promote learning environment free of fears and dangers among staff and students through safety measures for personnel management, the safety measures adopted by principals for personnel management prevent physical attacks, violence and emotional disorder among staff and students of secondary schools in Enugu State.

The second findings of the study revealed that human security management technique and effective management of Post Basic Schools in Adamawa State, Nigeria is statistically significant at $F_{(1, 32)} = 9.460$, $p < .05$). The major findings were that to a very high level, Post Basic School principals deploy school personnel, parental participation and Rapid Armed Response (Policemen) in combating insecurity in their respective schools. This finding corroborate with that of [29] whose findings indicated that human security measures were adopted by principals in public secondary schools in Anambra State. This finding agrees with that of Onuorah and Nwankwo (2020) whose findings indicated that principals of public secondary schools in Anambra State utilize human security management practices to a low extent. [32] further revealed that principals employ security guards, contract private security company to provide school security, collaborate with local vigilante groups to provide for school security, employ a security consultant for issues concerning the security of their respective schools for effective administration of public secondary schools. This finding however disagrees with the findings of [43] whose findings revealed that majority of the school reacted negatively to all the items on the table. However, this result shows that the public secondary school administrators did not make sufficient use of security safety techniques for management of public secondary schools in Anambra State. [43] further revealed that principal's deployment of the security safety techniques for management of public secondary schools in Anambra State was poor. The finding agrees with that of [28] whose findings revealed that it is acceptable to have staff and student identity cards, staff code of conduct and conflict resolution management programmes to help the staff as well as the students know how to resolve their disputes. The respondents agreed too that there is need to have constant searches of student's lockers and boxes to seize weapons and dangerous objects from the students. In contrast to the findings of this study, [32] however revealed that secondary school principals to a low extent collaborate with the police to ensure security in the school for effective administration of public secondary schools. This finding however disagrees with of [28] whose findings showed among others that some security devices for the improvement of security situations as well as the emergency response plans for managing security in public secondary schools were not available in most schools.

The third finding of the study revealed that technological security management technique and effective management of Post Basic Schools in Adamawa State, Nigeria statistically significant at $F_{(1, 33)} = 9.860$, $p < .05$. Majorly, the findings revealed that Post Basic School principals use; Hand- held detectors, Metal detectors and Closed-Circuit Television (CCTV) systems, including the videoing and storing of video surveillance footage whether analogue or digital to a very high level. This finding however disagrees with the findings of [42], whose findings revealed that the extent to which principals apply staff training, use of video surveillance cameras, physical access control, radio and alarm systems and computer assisted programmes as security management practice is to a low extent. This finding agrees with that of [28] whose findings revealed that secondary school principals fail to utilize technological security gadgets for effective school administration. The findings corroborate with that of [27] whose findings revealed that technological security measures and staff performance are significantly related. This finding disagrees with that of Nwobodo et al (2023) whose study on institutional security concluded that lack of technical know-how on the use of security devices by the security personnel as well as illiterate in the aspect of law and governance which is ambivalent to their nature of work. Subsequently, this is in line with the findings of [33] whose findings revealed that there is a significant relationship between safety measures

planning for quality public senior secondary school administration in River State. Also, [27] showed that security devices for improving security in public secondary schools are not generally available. [2], who asserted that inadequate incentive programmes, poor conduct of regular safety inspection, and unavailability of security gadget, like CCTV, lack of control on access, lack of man guard create unrest thereby affecting effective management of school. Andrew concluded that safety measures are very necessary to support academic success of students by creating orderly learning environment devoid of risks, fear of danger. However, the findings were contradicted by [18] whose finding revealed among others that some security devices for the improvement of security situations as well as the emergency response plans for managing secondary schools were not available in most schools. The disagreement in findings could be attributed to difference in geographical locations of the studies, and the period they were carried out. The possible explanation for these disagreements could possibly be due to Governor Ahmed Fintiri's intervention in secondary schools in Adamawa State.

Lastly, the regression model indicates that there is a significant relationship between the predictors (physical security management, human security management, technological security management) and effective management of Post Basic Schools, as evidenced by a significant F-statistic (F=5.996, p < .05). This suggests that at least one of the predictor variables has a non-zero effect on effective management of Post Basic Schools. It can be concluded that technological security management technique makes the strongest unique contribution to explaining effective management of Post Basic Schools in Adamawa State, Nigeria when controlling for the variance explained by all other variables in the model, as it has the largest beta coefficient of .480. In contrast, human security management technique makes a comparatively smaller unique contribution, with a beta value of .195. This finding corroborate with that of [1] whose findings revealed that there was a significant relationship between the school security measures (physical and technological) and staff job performance at public secondary schools located in Ilorin Metropolis. [1] further indicated that ensuring school safety implies freedom from risk, protection of lives and properties of the school members and the school, and reduction of intra and inter-school conflict while upholding quality education. The finding agrees with that of [14] whose findings revealed that there is a significant relationship between physical security measure and effective management of public secondary schools in Lagos State, Nigeria (r=.672, p <.05). The study therefore concluded that safety and security planning promote effective management of public secondary schools in Lagos State, Nigeria.

10 Conclusion

Based on the findings of the study, it was concluded by the researchers that the institutionalization of security safety techniques in public secondary schools in Adamawa State could enhance effective management of Post Basic Schools in the State. The researchers concluded that safety measures adopted by principals plays a significant relationship in the management of public secondary schools. The researchers envisaged that if secondary school principals utilize the immense benefits of physical, human and technological security management techniques in their daily service delivery; the management of Post Basic Schools in the State would be greatly enhanced.

11 Recommendations

Based on the findings of the study, the following recommendations were made:
1. Principals should endeavor to always use warning signs on perimeter fence, burglar proofing on windows and, protective lighting and other barriers (such as security gate across a passage) as these could further enhance effective school administration.
2. Federal government, State Government and other non-governmental organizations should ensure principals deploy school personnel, parental participation and Rapid Armed Response (Policemen) in combating insecurity in their respective schools by providing them with the necessary manpower requirements and financial support.
3. Post Basic School principals should further enforce the use of Hand- held detectors, Metal detectors and Closed-Circuit Television (CCTV) systems, including the videoing and storing of video surveillance footage whether analogue or digital, as this would enhance the quality of school management.
4. Since technological security management technique make the strongest unique contribution to explaining effective management of Post Basic Schools in Adamawa State, Nigeria when controlling for the variance explained by all other variables in the model, as it has the largest beta coefficient of .480, the State government should ensure Hand- held detectors, Metal detectors and Closed Circuit Television (CCTV) systems, including the videoing and storing of video surveillance footage whether analogue or digital are made readily available as these could further improve the management of Post Basic Schools.

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COMBATING SECURITY CHALLENGES IN THE NORTH-EAST OF NIGERIA: JUSTIFICATION FOR AN ANTI-TERRORISM COURT

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Abstract

The northeastern region of Nigeria faces significant security challenges due to the activities of terrorist groups like Boko Haram and ISWAP, resulting in violence, loss of lives, and socioeconomic disruption. Numerous deaths, large-scale displacement and social upheaval in the surrounding areas have been brought about by these organization acts of widespread violence. This paper highlights how vital it is to set up specialized anti-terrorism courts in order to successfully handle these critical problems. It emphasizes the shortcomings of the current legal systems in prosecuting terrorism-related offences by looking at the security environment today and the significant effects of insurgencies on national stability and governance. In order to address these concerns strategically, this paper examines the pressing need for specialized anti-terrorism courts. Through an examination of the state of community security and current legal affairs, it amplifies the shortcomings of the current legal systems in successfully prosecuting offences related to terrorism. Aiming to defend human rights, accelerate trials, and improve judicial efficiency all of which will increase public confidence in the legal system, dedicated courts should be established. This paper makes the case that anti-terrorist courts can handle particular legal issues about terrorism, enhance trial outcomes, and operate as a deterrence against further violence by referencing comparative legal frameworks and global best practices. Ultimately the establishment of these courts is necessary to bring about justice, restore peace, and bolster Nigeria's resolve to fight terrorism.

Keywords: Security, North-East, Nigeria, Anti-Terrorism and Court.

1.0 Background to the study

Persistent security challenges, primarily from terrorist organizations like Boko Haram and the Islamic State in West Africa Province (ISWAP), have afflicted the northeastern part of Nigeria. Numerous lives have been lost, infrastructure has been destroyed, and millions of people have been forced to flee their homes as a result of the extensive havoc these groups have wreaked. The intricacy and tenacity of these extremist groups have brought to light serious shortcomings in Nigeria's legal and judicial systems, especially with regard to the prosecution of terrorism-related offenses, in spite of continuous military operations and counterterrorism programs. The creation of a dedicated anti-terrorism court would provide a more concentrated, effective, and safe legal procedure for resolving cases involving terrorism, taking into account the scope and complexity of offenses connected to insurgencies. An anti-terrorism court would improve Nigeria's capacity to fight terrorism, prosecute offenders, and offer a more thorough legal framework for averting such assaults by expediting the judicial process.

1.1 Aim and Objective

This essay will examine Nigeria's need for an anti-terrorism court, especially in light of the region's continuous security concerns, as well as the potential benefits of having such a court for the nation's counterterrorism initiatives.

1.2 Methodology

This paper deploys doctrinal methodology. Doctrinal research is a study methodology that focuses on evaluating and interpreting legal documents, including legislation, case law, regulations, and treaties.

1.3 Security Challenges in Nigeria

Nigeria's northeast region suffers from serious security issues, mostly caused by the Boko Haram insurgency and its offshoot, the Islamic State West Africa Province (ISWAP). Since 2009, these gangs have tormented the area, resulting in thousands of fatalities, widespread displacement, and infrastructure destruction. Section 14(2) (b) of the Nigerian Constitution requires the government to protect the safety and well-being of its citizens. Despite this, security forces have been overrun by rebel activity, resulting in widespread instability. The legal foundation for terrorist prosecutions is provided by the Terrorism (Prevention) Act of 2011, as revised in 2013. However, the volume of cases in current courts frequently overwhelms them, and delays impede the administration of justice. The rule of law is hampered by the difficulty of quickly punishing rebels or collaborators, which feeds a cycle of impunity. Counterterrorism measures are further complicated by security services' struggles with poor intelligence sharing and cooperation with judicial agencies.

As a legal remedy, establishing a dedicated anti-terrorism court would improve the effectiveness of terrorism-related case prosecutions, guarantee accountability, and support regional security initiatives.

1.4 Existing judicial methods and their drawbacks

The Terrorism (Prevention) Act of 2011, revised in 2013, forms the basis of Nigeria's current judicial approaches to counterterrorism. It offers the legal foundation for prosecuting offenses related to terrorism. These methods do, however, have important drawbacks.

1. Overwhelmed Courts: A large number of cases, particularly those involving terrorism, are piled up in Nigeria's ordinary courts. Slow trials frequently lead to extended pretrial detention, which violates the rights of the accused under Section 35 of the Nigerian Constitution (right to a fair trial and prompt proceedings).

2. Shortage of expertise: Judges in regular courts may not possess a specific understanding of handling terrorism charges. Specialized legal knowledge is needed for complex matters including sensitive intelligence, international law, and counterterrorism tactics, which may not be available in normal courts.

3. Problems related to evidence and witness protection: It can be challenging to compile reliable evidence against terrorists, and witnesses are sometimes at risk of intimidation or reprisal. Although witness protection is guaranteed by the 2015 Administration of Criminal Justice Act (ACJA), its application in terrorism cases is still patchy, which reduces the efficacy of prosecutions.

1.5 Justification for Establishing an Anti-Terrorism Court

Extremist organizations, particularly Boko Haram and the Islamic State West Africa Province (ISWAP), have been the driving forces behind a lengthy struggle in the North-East area of Nigeria. These organizations have brought about great pain, which has resulted in fatalities, community uprooting, and pervasive insecurity. The Nigerian government has responded with both military operations and legislative changes, but the legal of counter terrorism has been much slower. To improve the efficacy of the legal response to terrorism, ensure that justice is done, and bring stability back to the area, an anti-terrorism court must be established in the North-East.

1. Specialized Judicial Focus: The need for a specialized court that only considers terrorism cases is one of the main arguments in favor of creating an anti-terrorist court. The backlog of civil and criminal cases in Nigeria's current court system frequently causes delays in the prosecution of terrorist suspects. These hold-ups cause the public to lose faith in the legal system and let suspects remain in custody without being given the opportunity to face prosecution for their charges. For example, reports suggest that a large number of people, especially those associated with Boko Haram, have been detained for years without being given the opportunity to face prosecution for terrorism related to charges. In Kenya, the implementation of Anti-Terrorism Courts after the 2013 Westgate Mall attack enabled the prompt prosecution of terrorism suspects, proving the efficacy of specialized courts in handling such cases. The creation of a dedicated court would give priority to these cases, guaranteeing prompt adjudication.

2. Expertise in Counter-Terrorism Law. Terrorism cases often mention complicated legal issues, such as using intelligence evidence, applying anti-terrorism laws, and finding a balance between national security and human rights. Regular courts might lack the specialized knowledge needed to handle these complexities well. An anti-terrorism court in the North-East would have judges and legal staff specifically trained in counter-terrorism law. This expertise is vital for ensuring that cases are judged fairly and in accordance with Nigerian law and international standards. Countries like France have set up specialized courts for terrorism cases, leading to more informed and effective legal processes.

3. Enhanced cooperation with Security Agencies. Prosecuting terrorism cases ofen necessitates strong cooperation between the judiciary and security bodies, including the Nigerian military and the Department of State Services (DSS). These organizations collect essential intelligence and evidence during counter-terrorism efforts that must be presented in court. An anti-terrorism court would enhance communication and collaboration between the judiciary and security agencies, ensuring that important evidence is effectively utilized in prosecutions. For instance, the United States has specialized courts for terrorism cases that allow for the secure management of classified information, which has been crucial in prosecuting high-profile terrorism suspects. Implementing a similar system in Nigeria would improve the effectiveness of prosecutions and ensure justice is achieved.

4. Protection for Witnesses and Victims. The prosecution of terrorism cases frequently faces hurdles due to witness intimidation. Those who might testify against terrorists often encounter threats and violence from extremist groups, which can discourage them from coming forward. The current judicial framework offers limited protections for witnesses, leaving them at risk of retaliation. A dedicated anti-terrorism court would establish strong witness protection programs to ensure the safety of individuals willing to testify.

1.6 Structure of an Anti-Terrorism Court

The North-East region of Nigeria has faced significant challenges due to terrorism, especially from the violent actions of Boko Haram and ISWAP. To effectively tackle the complexities involved in prosecuting terrorism-related offenses, it is crucial to establish a specialized anti-terrorism court. This court would not only streamline the prosecution process but also ensure that cases are overseen by professionals skilled in counter-terrorism law. This section details the proposed design and functioning of such a court, emphasizing how it can be adapted to address the specific needs of the North-East.

1. **Court Structure**. The Anti-Terrorism Court in the North-East would operate as a distinct division of the Nigerian judiciary, having exclusive authority over terrorism-related crimes. Its design should accommodate the unique challenges that arise in terrorism cases, including the necessity for expertise in counter-terrorism law, safeguarding witnesses and victims, and securely managing classified intelligence.

a. **Composition of the Court.** The court should be composed of judges, prosecutors, and defence attorneys who possess specialized knowledge in terrorism law and national security. This would necessitate developing a new group of legal professionals trained to navigate the complexities of terrorism cases, which often involve interpreting intelligence reports, addressing cross-border legal issues, and understanding human rights law. For instance, India has established special courts under the National Investigation Agency (NIA) to handle terrorism cases, staffed by judges experienced in national security matters, which aids in delivering informed rulings.

2. Geographical Location and Accessibility.

Since the northeast is the region most affected by terrorism, the anti-terrorism court needs to be situated within this area. This would make it easier for victims, witnesses, and security agencies to access the court, minimizing logistical issues related to transporting suspects and evidence over long distances, and allowing for quicker responses to new developments in ongoing cases.

3. Court Operation

The functioning of the Anti-Terrorism Court would be based on principles of efficiency, transparency, and fairness. It must strike a balance between the need for prompt justice and the obligation to uphold the rights of suspects, victims, and witnesses. Important operational aspects would include specialized trial procedures, secure handling of evidence, witness protection programs, and close collaboration with security agencies.

a. **Specialized Trial Procedures**

The Anti-Terrorism Court would follow an expedited procedure to resolve cases quickly while ensuring fairness. This would involve prioritizing terrorism-related cases by minimizing procedural delays that typically affect regular courts. For instance, strict deadlines for evidence submission and witness examination could be set to prevent unnecessary delays. In countries like Pakistan, Anti-Terrorism Courts (ATCs) were created to resolve cases within a specified timeframe, helping to alleviate the backlogs that regular courts often experience. Nigeria's anti-terrorism court could implement similar time-sensitive trial procedures to ensure that cases do not linger indefinitely.

b. **Handling Classified Evidence**

Terrorism trials often involve classified materials, including intelligence reports, surveillance information, and intercepted communications. The Anti-Terrorism Court must implement secure procedures for managing this type of evidence, ensuring that sensitive information does not jeopardize ongoing security efforts. For example, the United Kingdom's Special Immigration Appeals Commission (SIAC) handles sensitive evidence in national security cases by allowing "closed material proceedings," where evidence is shown to the judge without being revealed to the defendant for security reasons. Nigeria could establish similar protocols by incorporating safeguards to respect the rights of the accused while also protecting national security interests.

4. Precedents and International Examples

Various countries confronting terrorism have established specialized courts to manage terrorism-related offenses effectively and with the requisite expertise. These international examples offer valuable insights into how Nigeria might structure and operate its anti-terrorism court.

a. Egypt. In Egypt, special terrorism courts were created to address the escalating threat of terrorism, particularly in the wake of the unrest that began in 2011. These courts possess jurisdiction over terrorism cases and are designed to expedite legal proceedings while navigating the complexities of national security law. Their expedited processes have been credited with minimizing case backlogs and ensuring that terrorism suspects are brought to justice promptly.

b. Pakistan. Pakistan established its Anti-Terrorism Courts (ATCs) in response to the rising incidents of terrorism throughout the nation. These courts have facilitated the prompt administration of justice in terrorism-related cases,

featuring specialized judges and expedited procedures. The creation of the ATCs has notably enhanced Pakistan's capacity to address terrorism cases, providing a model that could be relevant for Nigeria.

a.   Case Studies of Specialized Courts for Terrorism

1. Special Anti-Terrorism Courts in Egypt. In the wake of the Arab Spring and subsequent terrorist attacks, Egypt established Special Anti-Terrorism Courts in 2015. These courts were created to expedite the prosecution of terrorism-related offenses, which had intensified.

Function; The Egyptian judiciary set up these courts with a mandate to handle cases involving organized terrorist groups, particularly those linked to the Muslim Brotherhood and ISIS. The courts operate under the authority of the Emergency Law, allowing for accelerated procedures and limited appeals.

Impact; The establishment of these courts has resulted in quicker trials, with many cases being resolved within months. However, the courts have faced criticism for lacking transparency and for the potential violation of defendants' rights. Human rights organizations have raised concerns about the fairness of trials, often citing reports of coerced confessions and inadequate legal representation. While the Special Anti-Terrorism Courts in Egypt have increased the efficiency of the judicial process regarding terrorism, they also highlight the delicate balance between security and civil liberties.

2. Counter-Terrorism Court in Pakistan. In response to rising terrorism, Pakistan established the Counter-Terrorism Court (CTC) in 2013 as part of a broader strategy to enhance the legal framework for combating terrorism.

Function; The CTCs are set up in each province, specifically tasked with adjudicating terrorism cases under the Anti-Terrorism Act. These courts operate with special procedures that allow for expedited hearings and trials.

Impact; The CTC has had a significant impact on the prosecution of terrorism cases in Pakistan. Reports indicate that the court has improved conviction rates, with a higher number of terrorists being sentenced compared to previous years. However, concerns about judicial independence and the potential for misuse of power remain prevalent. Human rights advocates argue that the rapid trial process may overlook essential due process rights.

The Counter-Terrorism Court in Pakistan demonstrates the potential benefits of specialized courts in dealing with terrorism while also emphasizing the need for safeguards to protect civil rights.

3. Special Courts in Iraq. After the rise of ISIS, Iraq faced a critical need for specialized judicial mechanisms to manage the overwhelming number of terrorism cases. In 2016, the Iraqi government established Special Courts to handle these cases effectively.

Function; The Special Courts operate under the Iraqi Counter-Terrorism Law, dealing with cases involving individuals accused of joining or supporting ISIS. These courts are designed to expedite the trial process and focus on national security concerns.

Impact; The establishment of Special Courts has been vital in managing the backlog of terrorism cases. However, they have faced significant criticism regarding due process and the treatment of defendants. Reports indicate that many trials are conducted in a manner that may not meet international standards for fair trials, with allegations of torture and coerced confessions. While the Special Courts in Iraq serve a crucial function in addressing terrorism, they underscore the challenges of maintaining fair judicial processes in high-stakes situations.

4. Anti-Terrorism Courts in Nigeria. In Nigeria, the ongoing conflict with Boko Haram and other terrorist groups has prompted discussions on establishing specialized Anti-Terrorism Courts. Although formal courts have yet to be fully implemented, existing structures under the Terrorism (Prevention) Act 2011 show the need for specialized mechanisms.

Function; Proposed Anti-Terrorism Courts would focus on expediting trials for terrorism offenses, ensuring that judges are trained in terrorism law, and providing a victim-centric approach to justice.

Impact; Implementing such courts could significantly enhance Nigeria's ability to address terrorism efficiently and justly. However, challenges such as corruption, inadequate legal infrastructure, and human rights concerns must be addressed to ensure their effectiveness.

The potential establishment of Anti-Terrorism Courts in Nigeria represents a proactive step toward combatting terrorism, but careful consideration of judicial integrity and human rights is essential for success.

b.   Obstacles and Criticism

The establishment of Anti-Terrorism Courts in Northeast Nigeria is a critical step toward addressing the pervasive security challenges posed by terrorism. However, several challenges and criticisms must be taken into account to ensure these courts function effectively and justly. This section explores these issues, supported by relevant cases and legal principles.

1. Due Process Concerns

One of the most significant challenges facing Anti-Terrorism Courts is the potential violation of due process rights. The quickening pace of terrorism trials may lead to rushed proceedings where defendants do not receive adequate legal

representation. For example, in the case of **Mohammed v. State (2018),** the Nigerian Supreme Court highlighted the importance of due process in legal proceedings, emphasizing that every accused person must be afforded the right to a fair trial. Failure to adhere to these principles risks wrongful convictions and undermines the legitimacy of the courts

2. Human Rights Violations

The fight against terrorism can lead to human rights abuses, particularly in regions with heightened security concerns. Reports from organizations like Amnesty International have documented instances of torture and extrajudicial killings by security forces in Nigeria. If Anti-Terrorism Courts do not implement strict safeguards, they may inadvertently facilitate such abuses. The African Charter on Human and Peoples' Rights (Article 5) prohibits torture and inhumane treatment, underscoring the necessity of protecting human rights within the judicial framework.

3. Resource Constraints

Establishing requires substantial resources, including trained personnel and infrastructure. In Northeast Nigeria, ongoing conflict has strained governmental resources, making it challenging to allocate sufficient funding for specialized courts. The Nigerian Constitution *(Section 6(6)(b))* grants courts the power to determine their own jurisdiction, but without adequate resources, these courts may struggle to function effectively.

c.   Recommendations

To effectively combat the security challenges posed by terrorism in Northeast Nigeria through the establishment of Anti-Terrorism Courts, the following recommendations are proposed:

Establish Clear Legal Frameworks. Comprehensive and precise legal frameworks that define terrorism and related offenses should be developed. These include establishing clear guidelines on what constitutes terrorist activities to prevent overreach and ensure that individuals are prosecuted appropriately. These frameworks should be aligned with international standards to uphold human rights.

Implement Strong Safeguards for Due Process. Anti-terrorism courts must prioritize due process rights to protect individuals from wrongful accusations and convictions. This includes ensuring access to competent legal representation, allowing for adequate time to prepare defenses, and conducting fair and transparent trials. Implementing these safeguards will help build public confidence in the judicial process.

Monitor and Evaluate Court Operations. Establishing mechanisms for regular monitoring and evaluation of Anti-Terrorism Courts is essential to assess their effectiveness and identify areas for improvement. This includes analyzing case outcomes, the adherence to due process, and the overall impact on community security. Feedback from stakeholders, including legal experts and community members, should be incorporated into evaluations.

d.   Conclusion

The establishment of Anti-Terrorism Courts in Northeast Nigeria represents a critical step toward enhancing the judicial response to the region's severe security challenges. By addressing the unique complexities of terrorism-related offenses, these specialized courts can improve the efficiency of the legal process, uphold victims' rights, and foster public trust in the justice system. Ultimately, while Anti-Terrorism Courts can play a significant role in combating terrorism, they must operate within a broader strategy that includes preventive measures, rehabilitation, and community engagement. By adopting a holistic approach, Nigeria can make meaningful strides toward restoring peace and security in the Northeast, ensuring justice is served without compromising human rights.

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INNOVATIVE APPROACH TO HEALTH EDUCATION IN CRISIS AFFECTED AREAS IN THE NORTH EAST OF NIGERIA

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ABSTRACT

This paper explores innovative strategies for delivering health education in crisis-affected areas of northeastern Nigeria. Amidst ongoing conflict and displacement, traditional health education methods face significant challenges. This study investigates alternative approaches, including mobile health units, digital platforms, and community-based interventions, aimed at improving health literacy and outcomes in these regions. By examining case studies and pilot programs, the paper highlights the effectiveness of these methods in addressing the unique needs of affected populations. The findings underscore the importance of adaptive and resilient health education systems in enhancing public health and well-being in crisis settings.

KEYWORDS: Digital platforms, community-based interventions, public health, conflict zones, health literacy.

1 INTRODUCTION

The North East region of Nigeria has been severely impacted by ongoing crises, including insurgency, internal displacement, and environmental degradation have severely affected the regional economy (Chukwuma, A., & Nwachukwu, E. 2022)[1]. Health education and crisis management in Nigeria are challenges that undermined the healthcare infrastructure and access to health education, exacerbating the vulnerability of populations in the area (World Health Organization 2021)[3]. Addressing health education requires innovative and adaptive strategies to overcome barriers and meet the unique needs of the affected communities.

2 UNDERSTANDING THE CONTEXT

1. Crisis Impact: The persistent conflict and violence have led to significant disruptions in healthcare services (Ahmed, L., & Yusuf, M. 2023)[2]. Innovative strategies for health education in crisis settings: A case study from North East Nigeria. Many health facilities have been damaged or destroyed, and the displacement of communities has further strained resources.

2. Access Challenges: Access to education is limited due to insecurity, and traditional methods of health education may not be feasible (United Nations. 2023)[3]. improving health education in conflict zones the displaced populations often live in temporary shelters with limited infrastructure.

2.1 INNOVATIVE APPROACHES TO HEALTH EDUCATION

1. **Technology-Driven Solutions**

   - *Mobile Health Units:* Smith, J. A., & Roberts, L. M. (2022)[5]., Stated that health education interventions in conflict zones will be effective if deploying mobile health units equipped with telemedicine capabilities can bridge the gap between affected populations and health professionals. These units can provide real-time consultations, diagnostics, and health education.

   - *SMS and Voice Messaging*: Leveraging mobile phones to disseminate health information through SMS or voice messages can reach individuals in remote or insecure areas. Tailored messages on hygiene, nutrition, and disease prevention can be sent regularly.

   - *E-Learning Platforms:* Developing online platforms or apps that offer health education materials in local languages can provide accessible information to both displaced individuals and health workers.

2. **Community-Based Approaches**

   - *Peer Educators and Community Health Workers:* Training local individuals as peer educators or community health workers can facilitate the dissemination of health information. These individuals are often more trusted by the community and can provide education on health practices, disease prevention, and the importance of seeking medical care.

- *Community Workshops and Radio Programs:* Implementing innovative health education programs in North East Nigeria involves organizing workshops and radio programs in collaboration with local leaders can engage the community in health education. Radio, in particular, is a powerful tool in areas with limited access to other forms of media (Nguyen, T., & Bello, R. 2023)[6].

3. Integration with Humanitarian Efforts
- Health Education as Part of Emergency Relief: Integrating health education into emergency relief efforts ensures that it is part of the immediate response. Providing educational materials alongside food, water, and shelter can help address health needs from the outset.
- Collaboration with NGOs: Partnering with non-governmental organizations (NGOs) that have experience working in crisis settings can enhance the effectiveness of health education programs. These organizations can offer logistical support and expertise in tailoring interventions to the local context.

4. Innovative Educational Materials
- Visual and Interactive Content: Using visual aids, such as posters and videos, can help overcome literacy barriers and engage diverse audiences. Interactive content, including quizzes and games, can make learning about health more engaging and memorable.
- Localized Content: Developing educational materials that reflect local languages, cultures, and health challenges ensures that the information is relevant and accessible to the target population.

5. Monitoring and Evaluation
- *Feedback Mechanisms:* Innovative approaches to health education in crisis-affected regions of North East Nigeria. Implementing systems to gather feedback from the community on the effectiveness of health education initiatives can help refine and improve the programs. Surveys, focus groups, and interviews can provide valuable insights (Ogunleye, T. 2021)[7].
- *Data-Driven Approaches:* Utilizing data to track health outcomes and educational impact can guide decision-making and resource allocation. This includes monitoring changes in health behaviors and disease prevalence in response to educational interventions.

3 CONCLUSION
Innovative approaches to health education in crisis-affected areas of North East Nigeria are crucial for addressing the complex challenges faced by these communities. By leveraging technology, community-based methods, and integrating health education into broader humanitarian efforts, it is possible to improve health outcomes and build resilience in these vulnerable populations. Effective implementation of these strategies requires collaboration between government agencies, NGOs, and local communities to ensure that health education efforts are sustainable and impactful.

4 SUGGESTION
1. Leveraging Mobile Technology: Develop and implement mobile health applications tailored to the needs of crisis-affected populations (Federal Ministry of Health Nigeria, 2022)[8]. Health education in conflict-affected areas: Case study of North East Nigeria. Federal Ministry of Health. These apps can provide critical health information, facilitate telemedicine consultations, and enable access to emergency health services. Given the high mobile phone penetration, this approach can enhance reach and engagement.
2. Community-Based Health Education Programs: Train local health workers and community leaders to deliver health education in a culturally sensitive manner. These programs should focus on preventive health measures, maternal and child health, and disease management. Utilizing local languages and traditions will improve understanding and adherence.
3. Partnership with Local Organizations: Collaborate with NGOs and local organizations to integrate health education into existing humanitarian aid efforts. These partnerships can leverage established trust and networks to disseminate health information more effectively.
4. Use of Radio and Local Media: Develop health education campaigns using local radio stations and media outlets. Radio programs can reach a broad audience, including those who may have limited access to other forms of media. Programs should be interactive, allowing listeners to ask questions and seek advice.
5. Interactive Workshops and Community Events: Organize health education workshops and events that actively involve the community. These events can focus on practical skills, such as basic first aid and hygiene practices, and provide a platform for people to discuss health concerns and solutions.
6. Incorporate Traditional Knowledge: Integrate traditional health practices and knowledge with modern health education to create a more acceptable and effective approach. Engage traditional healers in educational efforts to bridge gaps between conventional and traditional health practices.

7. Utilize Data for Tailored Interventions: Enhancing health education during crises in Nigeria's North East. Collect and analyze data on health needs and challenges specific to different communities within the crisis-affected areas. Use this data to tailor health education initiatives to address the most pressing issues and ensure relevance (Adeyemi, F. 2023, January 15)[9].

8. Promote Resilience and Mental Health: Include mental health education and support as part of health education programs. Providing resources and coping strategies for mental health can help communities build resilience in the face of ongoing crises.

9. Emergency Preparedness Training: Incorporate training on emergency preparedness and response into health education programs. This can empower communities to better handle health crises and disasters, improving overall resilience.

By implementing these innovative approaches, health education in crisis-affected areas of Nigeria can become more effective, accessible, and responsive to the needs of the population.

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SECURITY ISSUES IN THE NORTHEAST: THE ROLE OF UNITED NATIONS CHILDREN'S FUND IN ADDRESSING EDUCATIONAL CRISES IN BORNO STATE

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Abstract

Security difficulties in northeastern Nigeria, notably in Borno state, have resulted in a major educational crisis. The Boko Haram insurgency in Borno state, Nigeria, has caused a major educational crisis, cumulating in murder of over 2,295 teachers and displacing thousands of students. In response, UNICEF has been working to provide emergency education assistance to affected children, enrolling approximately 750,000 children in schools constructing temporary learning spaces, and distributing educational resources. Although significant efforts have been made, major challenges persist, such as a 40% funding gap and the appalling conditions faced by displaced children. This report investigates UNICEF's role in addressing the educational crisis in Borno state. It focuses on the organization's activities, the obstacles they face, and the financing gaps in providing emergency education support to affected children. This paper aims to provide a complete picture of Borno state's educational crisis, as well as how UNICEF is addressing it. The findings proffer effective solutions to help to establish effective solutions for dealing with educational crises in conflict-affected areas, as well as guide policy and programming decisions to support the education sector in Borno state.

KEYWORDS: Security, UNICEF, Education, Borno State.

1 Introduction

In Northeast Nigeria, Borno State has been specifically affected by a long-lasting security crisis for over a decade. The Boko Haram insurgency, which began in 2009, has resulted in unprecedented levels of violence, displacement, and humanitarian needs. Despite the security challenges, education remains a critical component of the humanitarian response, providing a sense of normalcy and stability for children, promoting social cohesion and community resilience, and supporting future economic growth and stability. The United Nations Children's Fund (UNICEF) has been at the forefront of the humanitarian response, **engaging in efforts to** address the educational needs of children affected by the conflict through emergency education services, infrastructure rehabilitation, teacher training, and advocacy for children's rights. This paper aims to examines the role of UNICEF in addressing the educational crisis in Borno state, Northeast Nigeria, and offers a comprehensive analysis of the security situation the importance of education amidst the crisis, and the interventions implemented by UNICEF to support the education sector.

2. OVERVIEW OF SECURITY CHALLENGES IN BORNO STATE.

1. **Terrorism and Insurgency:** Boko Haram's violent campaign against Western-style education has led to the destruction of schools, abduction of students and teachers, and disruption of the education system. (INTERNATIONAL CRISESGROUP, 2019, P.5)
2. **Kidnappings and Abductions:** The group's tactic of kidnapping students and teachers has created a climate of fear, making it difficult for students to access education and for teachers to teach. (AMNESTY INTERNATIONAL, 2018, P.10)
3. **Displacement and Migration:** The conflict has led to the displaced of millions of people, including students and teachers which has led to a lack of skilled workers and a decline in educational outcomes.
4. **Military Response:** The Nigerian military's response to the insurgency has also been criticized for its heavy-handed approach, which has led to human rights abuses and further destabilization of the region.

2.1 IMPACT OF THESE CHALLENGES ON EDUCATION.

1. **School Closures:** The conflict has resulted in the closure of schools, with many students unable to access education due to fear of violence or displacement.

2. **Destruction of Infrastructure:** The destruction of schools and educational infrastructure has led to a shortage of classrooms, teachers, and educational materials.
3. **Disruption of Academic Calendar:** The education system has been severely impacted by the conflict, leaving many students unable to finish their studies as the academic calendar remains disrupted
4. **Teacher Shortages:** The abduction and displacement of teachers have led to a shortage of qualified educators, further exacerbating the education crisis. (UNICEF, 2020)

2.2 CONSEQUENCES OF THESE CHALLENGES.

1. **Decline in Educational Outcomes**: The conflict has led to a major drop in educational outcomes, with many students unable to access or complete their education.
2. **Shortage of Skilled Workers**: The conflict has led to a shortage of skilled workers, as many students are unable to access or complete their education.
3. **Economic Consequences**: The decline in educational outcomes has resulted in decreased economic productivity. This situation further worsens the economic challenges facing the region

3.0 UNICEF'S PRIMARY INITIATIVES IN BORNO STATE TO IMPROVE EDUCATIONAL OUTCOMES

In response to the ongoing educational crises in Borno State, UNICEF has implemented several critical interventions aimed at improving access to quality education for vulnerable children and adolescents affected by conflict and the COVID-19 pandemic.

1. **Transformative Educational Programs:** UNICEF, in collaboration with the Norwegian government, has prioritized the transformation of educational systems through the 2023-2027 FGN/UNICEF-assisted Basic Education Program. This initiative focuses on skills development. It ensures that every child, particularly the most vulnerable, not only receives an education but also acquires essential skills for future success. (Abubakar, 2024). A significant component of this program is the National Skills Development Framework, which encompasses foundational, transferable, digital, and job-specific skills. This comprehensive framework outlines the core skills necessary for success in various fields, identifying essential means for realization through flexible and diverse learning pathways. Furthermore, the program includes initiatives that specifically target marginalized groups, ensuring that children from conflict-affected backgrounds are not left behind. (ABUBAKAR, 2024)
2. **Infrastructure Development and Support:** In collaboration with the European Union, UNICEF is addressing significant educational challenges in Borno State by constructing and renovating classrooms and toilet facilities. This initiative is expected to benefit at least 20,000 children and improve access to education for conflict-affected populations (UNICEF, 2021). The construction of 116 classrooms and 53 latrines is critical in supporting educational engagement in a region where over 1,400 schools have been destroyed due to conflict (UNICEF, 2021). These newly established facilities are designed not only to alleviate classroom congestion but also to enhance the learning environment, particularly for girls who face additional barriers to education.
3. **Innovative Learning Support in IDP Camps:** In addition to structural improvements, UNICEF has partnered with the Restoration of Hope Initiative (RoHI) to implement radio learning activities at the Muna Garage IDP Camp School. This initiative employs adolescent assistant teachers, such as Hauwa Bukar, to facilitate lessons for approximately 1,500 vulnerable children whose education has been significantly disrupted (UNICEF, 2021). The program features radio broadcasts that provide lessons three times a week, allowing children to engage with educational content despite the challenges posed by displacement and conflict. These adolescent assistants play a crucial role by translating lessons from Hausa to the Kanuri language, ensuring that students fully comprehend the material. Moreover, they are responsible for maintaining classroom order, marking scripts, and enforcing hygiene practices to mitigate the spread of COVID-19. This initiative not only addresses immediate educational needs but also empowers youth like Bukar, who balances teaching duties with her own studies while providing financial support to her family (UNICEF, 2021).

3.1 IMPACT OF THESE INTERVENTIONS

UNICEF's programs in Borno State have significantly contributed to enhancing community engagement and providing qualitative support, as exemplified by the experiences of educators like Ngare Bukar, the head teacher at Modu Makaranta Primary School in Maiduguri. Bukar's journey from a lawyer to an educator reflects the profound impact of

UNICEF's initiatives, particularly in fostering a sense of purpose and community among teachers and students affected by conflicts.

1. **Teacher Training and Professional Development:** Through the Partnership for Learning for All (PLANE) project, UNICEF has facilitated on-the-job training for teachers in northeast Nigeria, including training in methodologies such as Teaching at the Right Level (TaRL) and psychosocial support Bukar credits UNICEF for enhancing his teaching capabilities, noting that the TaRL methodology has transformed learning outcomes for children in his school. He explains, 'In three weeks, you will see children identifying letters or reading,' highlighting the program's effectiveness in enabling children to achieve competencies that allow them to pursue further education (UNICEF, 2024).

2. **Community Support and Engagement:** Bukar's commitment to training other educators exemplifies the ripple effect of UNICEF's programs. After participating in various trainings, he organizes in-house sessions for his colleagues, ensuring that the knowledge gained is disseminated throughout the school. This approach not only enhances the skill sets of fellow teachers but also builds a supportive community dedicated to improving educational outcomes. Bukar states, "To support my teachers in their work better, I step down from all training, even if my school is not selected," illustrating his dedication to collective growth and development (UNICEF, 2024). This sense of community engagement is essential in areas where resources are limited, and collaboration can make a significant difference.

3. **Resilience Amid Adversity:** Despite facing personal tragedies, including the loss of two brothers to armed conflict, Bukar remains optimistic about the future of education in Borno. His story reflects the resilience cultivated through UNICEF's interventions, which not only enhance educational practices but also contribute to a supportive community framework. By investing in teachers and addressing the holistic needs of students, UNICEF is making strides in creating a more stable and engaged educational landscape in Borno State. Additionally, UNICEF's programs in Borno have profoundly impacted community engagement and qualitative support by empowering educators, fostering collaboration, and addressing the psychosocial needs of students. Through initiatives like PLANE, UNICEF is not just improving educational outcomes but also nurturing a resilient community capable of overcoming the challenges posed by conflict.

4. **Vocational Training and Empowerment:** Amina and Mohammed are among the 15,552 young people who have benefited from vocational training programs facilitated by UNICEF and BOSAME, funded through a European Union education intervention project. Amina, who was forced to drop out of school due to safety concerns and economic hardships, has turned her life around by acquiring skills that allow her to produce snacks and local drinks. She now earns approximately 15,000 naira (about 30 US dollars) monthly, enabling her to contribute to her family's needs. "With the money I earn from this business, my family and I survive," she shares, highlighting the direct benefits of vocational training on economic stability (UNICEF, 2021). This empowerment not only enhances individual livelihoods but also strengthens family units within the community.

5. **Supportive Ecosystem for Young Entrepreneurs:** Similarly, Mohammed, who had never attended school but learned the trade of cobbling, exemplifies how vocational training can lead to economic independence. With his newfound skills, he now earns between 6,000 and 15,000 naira monthly, enabling him to support his family and contribute to household expenses. "It feels good to be able to support my family," he expresses, emphasizing the emotional and financial relief that comes from being able to contribute (UNICEF, 2021). The program's support in providing a startup fund of 9,000 naira allowed him to acquire the necessary materials to begin production. BOSAME's initiative to link skilled trainees with local business owners further enhances employment opportunities and community integration, helping young people establish sustainable livelihoods.

6. **Building a Path to Education:** Both Amina and Mohammed's stories underscore the program's impact on not only immediate economic gains but also long-term educational goals. Amina is now pursuing her studies to become a teacher while also supporting her siblings' education. Mohammed, who has resumed his education in Primary 5, is motivated to enroll his siblings as well. This focus on education, alongside vocational training, exemplifies a holistic approach to community development, enabling individuals to envision a brighter future despite the odds stacked against them.

7. **Community Engagement and Networking:** UNICEF and BOSAME's strategies for community engagement extend beyond individual success stories. The program encourages access to training facilities for all certified graduates, allowing them to utilize equipment for production and sales. "We have told our instructors to provide access to all young persons trained by us for free," explains Umar Lawan, BOSAME UNICEF Focal Officer, emphasizing the program's commitment to fostering a supportive network for young entrepreneurs (UNICEF, 2021).. This collective approach strengthens community ties, enhances skill-sharing, and promotes an environment where young individuals can thrive together.

Overall, the impact of UNICEF's vocational training programs in Borno has created a ripple effect of empowerment, community engagement, and qualitative support. By equipping young people with practical skills and promoting

educational opportunities, UNICEF is not only meeting critical demands but also laying the groundwork for a more resilient and self-sufficient community in northeast Nigeria.

4.0 KEY CHALLENGES FACED BY UNICEF IN BORNO STATE INTERVENTION

1. **Security Issues**: The abolition of traditional leadership institutions such as chiefs in Borno State has engendered an unstable security situation thereby hampering the operation of UNICEF and other humanitarian agencies. There are considerable threats to the security of UNICEF officers and their collaborators due to the existence of non-state actors and the threats of abductions, mugging, and other acts of violence (UNICEF 2020).

2. **Logistical Challenges:** The availability of transport and the ability to move people and goods for work or develop a dependable supply chain has been hindered by the ruin of roads, bridges, and buildings. The lack of basic services such as health care, education, and sanitation has aggravated the humanitarian crisis in Borno State and the region in general.

3. **Funding Limitations:** Because of the magnitude and nature of the humanitarian situation in Borno State, there are relatively high resources estimated for UNICEF's activities, yet funding shortfalls have proven the organization's response ineffective. Rescue activities are rightly emphasized and thus overshadow other places of emphasis for instance the case of development assistance is where funding is currently lacking for a necessary measure (UNICEF, 2020).

4. **Community Engagement and Social Mobilization:** The conflict has generated burdens on both social structures and cultural practices thereby making it difficult to interact with local populations and sensitize them on issues such as vaccination and nutrition. Trust accrual is low considering that even UNICEF as humanitarian aid organization is defeatable to engagement and inclusion of people for mobilization of communities through humanitarian organizations.

5. **Health and Nutrition Challenges:** There is high disease burden with incidences such as malaria, cholera, measles ranking very high and hence making women and children vulnerable to health challenges. Healthcare services especially maternal and child health care services are not embraced hence that has brought a health problem in Borno State.

6. **Education Challenges:** There has been interruption in the education system with many schools being destroyed or closed and teachers and students either displaced or killed due to the conflicts. Lack of access to educational facilities has brought great challenges to children and especially girls who are extremely at the risk of losing their right to education.

4.1 RECOMMENDATIONS FOR IMPROVING EDUCATIONAL INTERVENTIONS.

1. The Nigerian government should prioritize the protection of schools and educational infrastructure to ensure that students can access education safely. Humanitarian organizations should provide support to displaced students and teachers to ensure that they can continue their education and teaching. The government should also address the root causes of the conflict, including poverty, inequality, and lack of access to education, to prevent further violence and instability.

2. **Create Temporary Learning Environment**: Open basic learning structures within the IDP camps and host communities during the first weeks or months of displacement so children can immediately be enrolled into school and receive their education. These spaces may be developed in tents, community halls or other structures and contain simple educational aids and equipment.

3. **Recruit and Train Teachers**: Hire teachers with adequate knowledge of the Boko Haram situation and best approach towards teaching young children in Borno State. Develop capacity on trauma sensitive Basic Education, Psychosocial Support and Conflict Sensitive Education to enable teachers to manage children caught up in the conflict. (UNICEF, 2018, PG 30).

4. **Focus on Girls' Education**: "As the timeless saying goes, if you educate a woman, you educate a nation." Some measures that we believe would help include putting in place structural measures such as offering scholarships, mentorship and other forms of assistance for girls to attend school. And Address issues that affects girls in school like Early marriages, Gender based violence and poor sanitation facilities to enhance a favourable learning environment. (UNICEF, 2018, P.30)

5. **Sensitization**: Also, to increase education literacy to parents and other members of the community, consult with local communities with an aim of mobilizing them on education sensitive issues and education related causes. (HOFFMAN, 2017, P.60)

5.0 CONCLUSION

UNICEF has greatly increased its support to Borno State, reaching children and families affected by the conflict. It provides essential services like education, health, and nutrition, such as establishing temporary classrooms and training

teachers. However, ongoing funding is necessary to maintain these educational programs. Education is crucial for restoring normalcy, promoting social integration, and enhancing problem-solving skills. There is an urgent need for governments, donors, and stakeholders to invest more in education in conflict-affected areas, especially in Borno State, to ensure sustainable development of educational systems.

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STRENGTHENING CROSS-BORDER LEGAL FRAMEWORKS: COLLABORATIVE APPROACHES TO ENHANCING SECURITY AND ADDRESSING HUMANITARIAN CHALLENGES IN NORTH-EAST NIGERIA

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Abstract

The North-East region of Nigeria has been plagued by persistent security threats, including insurgency, terrorism, and cross-border criminal activities, which have exacerbated humanitarian crises and undermined regional stability. This paper examines the critical need for enhanced cross-border legal frameworks to effectively address these challenges. By analyzing existing legal and regulatory mechanisms within Nigeria and its neighboring countries, the paper finds significant gaps and proposes strategies for fostering international collaboration. The paper explores the role of legal frameworks in facilitating joint security operations, improving intelligence sharing, and ensuring the protection of human rights in conflict zones. It highlights successful case studies of cross-border legal cooperation in other regions and applies these lessons to the North-East Nigerian context. Furthermore, the paper addresses the humanitarian impact of security issues, including displacement, access to healthcare, and the protection of vulnerable populations. In terms of methodology, this paper adopts a doctrinal approach. The paper recommends a multi-faceted approach that includes harmonizing legal standards, establishing robust mechanisms for cross-border coordination, and promoting joint research initiatives. By proposing actionable policy recommendations, the paper aims to provide a comprehensive framework for enhancing security and humanitarian response efforts in the North-East of Nigeria through strengthened international legal collaboration. This analysis contributes to the broader discourse on improving regional security and humanitarian outcomes, emphasizing the importance of united research efforts and collaborative legal strategies in addressing complex cross-border challenges.

KEYWORDS: Cross-Border; Legal Frameworks; Collaborative; Security; Challenges; North-East Nigeria

1. INTRODUCTION

The North-East of Nigeria has been a hotspot of conflict and instability due to the activities of insurgent groups like Boko Haram and its affiliates. This situation has led to significant humanitarian challenges, including large-scale displacement, human rights abuses, and disruptions in access to essential services. Given the cross-border nature of these issues, there is a pressing need for enhanced legal frameworks that promote regional cooperation and address both security and humanitarian concerns effectively.

2. STATEMENT OF THE PROBLEM

The ongoing insurgency in North-East Nigeria has resulted in persistent violence and insecurity. The activities of armed groups have not only destabilized the region but also had spillover effects on neighboring countries, including Chad, Cameroon, and Niger. These cross-border dynamics complicate the security situation and necessitate a coordinated regional response. The conflict has triggered a severe humanitarian crisis, with millions displaced and in urgent need of assistance. Human rights violations, including targeted attacks on civilians and infrastructure, further exacerbate the situation. Addressing these humanitarian issues requires a robust legal and operational framework that transcends national borders. Regional initiatives such as the Multinational Joint Task Force (MNJTF) and international efforts led by organizations like the United Nations play a crucial role in addressing the crisis. However, the effectiveness of these initiatives is often limited by gaps in legal coordination and implementation challenges.

3. METHODOLOGY

This research is not empirical but doctrinal. It relies on national and international laws, conventions, treaties, agreements, policies, etc. to which Nigeria has entered into and ratified.

4. RESEARCH QUESTIONS
The questions formulated in this doctrinal research otherwise called library center research are as follows:
1. Are there laws that govern inter-border security operations?
2. Are these laws (if any) adequate to combat transnational security challenges?
3. What are the *lacunae* in these laws?

5. LEGAL FRAMEWORK ON NIGERIAN SECURITY
The Nigerian Constitution of 1999 does not explicitly define or address terrorism in detail. Instead, anti-terrorism measures are addressed through various laws and amendments beyond the Constitution itself as follows:

a. Terrorism (Prevention) Act: The primary legal framework addressing terrorism in Nigeria is the Terrorism (Prevention) Act, 2011, which has been amended several times. This act defines terrorism and outlines severe penalties for those involved in terrorist activities. Key provisions include definition of terrorism, punishments, forfeiture of assets, preventive measures, national security agencies, the Nigerian Constitution provides for the establishment of security agencies like the Nigerian Police Force and the Department of State Services (DSS), which play a role in counter-terrorism efforts. While these agencies are not specifically mentioned in the context of terrorism, they have responsibilities that encompass national security, including counter-terrorism, and State Security. The Constitution grants the government the authority to declare a state of emergency in response to significant threats to national security, which can include terrorism. This provision is designed to allow for extraordinary measures in times of crisis, the Constitution protects fundamental human rights, and anti-terrorism laws and measures must align with these rights. This includes safeguards against arbitrary detention and ensuring that counter-terrorism actions respect constitutional guarantees.

Nigeria has developed a robust legal framework to address terrorism, primarily through specific laws designed to combat and prevent terrorist activities. Here are key laws related to terrorism in Nigeria: Anti-Terrorism Act, 2011 this Act complements the Terrorism (Prevention) Act by focusing on the broader implications of terrorism and its impact on national security. Counter-terrorism financing addresses issues related to the financing of terrorism, including measures to trace and seize funds used for terrorist activities. International cooperation includes provisions for cooperation with other countries and international organizations in combating terrorism. Cybercrime (Prohibition, Prevention, Etc.) Act, 2015 while not exclusively a terrorism law, is relevant due to the increasing use of technology by terrorist organizations. Cybersecurity Measures addresses crimes committed via the internet, including those related to terrorism, such as online radicalization and recruitment. It prescribes penalties for offenses that involve using cyberspace to facilitate terrorism. Money Laundering (Prohibition) Act, 2011 is crucial in the context of counter-terrorism financing, targeting the financial operations of terrorist organizations. Prevention of Money Laundering provides measures to prevent money laundering, including the identification and reporting suspicious transactions. Asset forfeiture allows for the forfeiture of assets acquired through money laundering, which may be linked to terrorist financing. National Security Agencies Act governs the operations of Nigeria's security agencies involved in counter-terrorism. Operational authority grants powers to agencies like the Department of State Services (DSS) and the Nigerian Police Force to conduct operations against terrorism. These laws collectively form the backbone of Nigeria's legal approach to tackling terrorism, focusing on prevention, prosecution, and the financing of terrorism, as well as enhancing international cooperation and improving internal security measures.

6. INSTITUTIONAL FRAMEWORK ON NIGERIAN SECURITY
Humanitarian challenges in the North-East of Nigeria, particularly due to the ongoing insurgency and conflict, are addressed through various institutional frameworks. These institutions aim to mitigate the impact of the conflict on civilians and provide assistance and protection to those affected. Some key laws and frameworks related to humanitarian challenges in the North-East include:

a. The National Emergency Management Agency (NEMA) Act, 1999 established NEMA as the primary agency responsible for disaster management and emergency response in Nigeria. Disaster management outlines NEMA's role in coordinating response efforts during emergencies, including conflict-induced crises. Coordination and relief provides for the coordination of relief efforts and the distribution of aid to affected communities.

b. The National Commission for Refugees, Migrants and Internally Displaced Persons (NCFRMI) Act, 2010 established the NCFRMI. The Act focuses on the welfare and rehabilitation of refugees, migrants, and internally displaced persons (IDPs). Protection and Assistance Commission is responsible for providing protection and assistance to IDPs, including those displaced by insurgency. Rehabilitation and Reintegration supports efforts to rehabilitate and reintegrate displaced persons into their communities.

c. The Internally Displaced Persons (IDPs) Policy, 2012 is a policy framework that guides the management of IDPs in Nigeria, including those affected by insurgency. Humanitarian assistance outlines the provision of humanitarian aid, shelter, and basic services to IDPs. Coordination and planning emphasizes the need for coordinated responses and planning among various stakeholders, including government agencies and NGOs.

d. The Nigerian Red Cross Society Act established the Nigerian Red Cross Society, which plays a significant role in providing humanitarian assistance during emergencies. Humanitarian aid provides emergency relief, medical care, and other forms of assistance to communities affected by conflict and disasters. Neutrality and Impartiality operates on principles of neutrality and impartiality, ensuring aid reaches all those in need without discrimination.

e. The Child Rights Act, 2003 is crucial for addressing the rights and protection of children affected by insurgency. Protection and welfare ensures the protection and welfare of children, including those displaced by conflict, against abuse, exploitation, and neglect. Access to services, a core part of the Act, provides for children's access to education, health care, and other essential services.

f. The Violence Against Persons Prohibition (VAPP) Act, 2015 addresses various forms of violence, including those impacting displaced persons and conflict-affected communities. Protection against violence provides legal protection against violence, including sexual and gender-based violence, which is prevalent in conflict zones. Support Services the Act mandates the provision of support services for survivors of violence.

g. International Humanitarian Law (IHL) is a party to various international conventions and treaties that govern the conduct of armed conflict and protect civilians. The Geneva Conventions and their additional protocols set out the rights of civilians and the conduct of hostilities, including protection for those affected by armed conflict. Human rights emphasize the need to protect human rights and provide humanitarian assistance in conflict situations.

h. The National Health Act, 2014 provides a framework for healthcare delivery and is relevant in addressing health challenges in conflict-affected areas. Health care access ensures access to healthcare services, including for displaced persons and those affected by insurgency. Emergency health services supports the provision of emergency health services during crises. These laws and frameworks collectively aim to address the complex humanitarian challenges in the North-East of Nigeria, focusing on disaster management, the protection of displaced persons, and the provision of essential services. They highlight the need for a coordinated and multi-faceted approach to alleviating the impact of the ongoing insurgency on affected communities.

7. UNITED NATIONS AND AFRICAN UNION FRAMEWORKS ON NIGERIAN SECURITY

The United Nations (UN) has been actively involved in addressing the insurgency in North-East Nigeria, primarily through humanitarian assistance, development support, and advocacy. Some of the key efforts made by the UN and its associated agencies include:

a. Humanitarian Assistance

i. United Nations Office for the Coordination of Humanitarian Affairs (OCHA) coordinates humanitarian responses and ensures that aid reaches those in need efficiently. It works with various humanitarian partners to provide emergency relief to internally displaced persons (IDPs) and communities affected by the insurgency. OCHA facilitates and mobilizes funding through the Humanitarian Response Plan (HRP), which outlines the needs and priorities for humanitarian assistance.

ii. The World Food Programme (WFP) provides food assistance and nutritional support to vulnerable populations affected by the conflict. It aims to address food insecurity and malnutrition among IDPs and host communities.

iii. The United Nations High Commissioner for Refugees (UNHCR) focuses on the protection, shelter, and assistance of IDPs and refugees. It provides essential services, including shelter materials, health care, and legal support.

iv. UNICEF works to protect children from the impacts of the conflict, providing education, psychosocial support, and protection services. It also addresses child malnutrition and other health issues exacerbated by the insurgency.

b. Development and Resilience Building

i. The United Nations Development Programme (UNDP) supports recovery and resilience-building efforts in conflict-affected areas. It helps communities rebuild infrastructure, restore livelihoods, and strengthen local governance, engaged in stabilization projects to support peacebuilding and development initiatives, aiming to create conditions for long-term stability.

ii. The United Nations Population Fund (UNFPA) Reproductive Health: UNFPA provides reproductive health services, including maternal care and support for survivors of sexual and gender-based violence (SGBV). It works to address the specific needs of women and girls in conflict settings.

c. Advocacy and Policy Support

i. Human Rights Council and Special Rapporteurs: The UN Human Rights Council and its Special Rapporteurs monitor and report on human rights violations in conflict zones. They advocate for the protection of civilians and the adherence to international humanitarian and human rights laws.

ii. UN Security Council: The Security Council has passed resolutions addressing the conflict in Nigeria and the activities of terrorist groups such as Boko Haram. These resolutions often include measures to enhance security and support counter-terrorism efforts.

d. Collaboration and Partnerships Coordination with Regional Organizations: The UN collaborates with the African Union to address regional security challenges and support peace and security initiatives in Nigeria Economic Community of West African States (ECOWAS) the UN works with ECOWAS on regional strategies to combat terrorism and support stabilization efforts in affected areas.

i. Partnerships with Non-Governmental Organizations (NGOs): The UN partners with various NGOs to implement humanitarian and development programs on the ground. These partnerships are crucial for delivering aid and services effectively.

e. Capacity Building Training and Support: The UN provides technical assistance and capacity-building support to Nigerian security forces and local governance structures to enhance their ability to respond to insurgency and protect civilians. In summary, the UN's efforts in North-East Nigeria involve a multi-faceted approach that includes humanitarian aid, development support, advocacy, and collaboration with regional and local partners. These efforts aim at alleviating the immediate impact of the insurgency and supporting long-term recovery and stability in the region.

8. JUDICIAL FRAMEWORK ON NATIONAL SECURITY AND TERRORISM

In addressing cross-border security issues affecting Nigeria's North-East, several landmark cases and legal decisions have shaped the legal landscape and influenced national security policies. some notable cases include:

a. Ajudua vs. Federal Republic of Nigeria (2021): This case involved a prominent criminal accused of various offenses, including those linked to cross-border criminal activities. The case highlighted the challenges in prosecuting individuals involved in transnational crimes and underscored the need for effective legal frameworks and international cooperation in tackling cross-border security threats, particularly in volatile regions like North-East Nigeria.

b. Federal Republic of Nigeria vs. Shettima (2017): This case centered on the prosecution of individuals suspected of terrorism-related activities in North-East Nigeria. It set a precedent for the application of the Terrorism (Prevention) Act, demonstrating the judiciary's role in interpreting and enforcing anti-terrorism laws in the context of ongoing insurgencies. It also highlighted issues related to evidence and the judicial process in terrorism cases.

c. Abubakar vs. Federal Republic of Nigeria (2015): This case involved individuals accused of cross-border trafficking and their link to insurgent groups in the North-East. The decision reinforced the legal approach to combating trafficking and related crimes that fund or support terrorist activities, emphasizing the need for robust enforcement and cross-border cooperation.

d. The Federal High Court's Ruling on the Boko Haram Insurgency (2014): This series of rulings involved cases related to the Boko Haram insurgency, particularly those involving the designation of Boko Haram as a terrorist organization and the related legal implications. The rulings helped establish the legal framework for designating and prosecuting terrorist organizations in Nigeria. They also provided guidance on how to handle cases involving the insurgency, including the seizure of assets and the restriction of the group's activities.

e. Federal Republic of Nigeria v. Umar Farouk Abdulmutallab (2012): Umar Farouk Abdulmutallab, also known as the "Underwear Bomber," attempted to detonate a bomb on a flight from Amsterdam to Detroit in December 2009. Though the incident occurred outside Nigeria, Abdulmutallab's Nigerian citizenship and his connections to extremist groups were significant. This case drew international attention and highlighted the global nature of terrorism and the need for robust counter-terrorism measures. It emphasized the importance of international cooperation and intelligence sharing in preventing terrorism.

f. Federal Republic of Nigeria v. Kabiru Sokoto (2013): Kabiru Sokoto was a key figure in the Boko Haram insurgency. He was arrested in connection with the 2011 Christmas Day bombing of a church in Madalla, Niger State, which killed over 40 people of Sokoto's trial was significant in the context of Nigeria's fight against Boko Haram. The case underscored the legal challenges in prosecuting high-profile terrorism suspects and the use of the Terrorism (Prevention) Act in securing convictions.

g. Federal Republic of Nigeria v. Mohammed Yusuf (2009): Mohammed Yusuf was the leader of Boko Haram, a militant Islamist group responsible for numerous terrorist attacks in Nigeria. Yusuf was captured and killed in police custody. Although Yusuf's death occurred before a full trial, the legal and human rights implications of his extrajudicial killing were significant. The case raised questions about the treatment of terrorist suspects and the adherence to legal and human rights standards.

h. Federal Republic of Nigeria v. Ahmed Salkida (2017): Ahmed Salkida, a journalist with links to Boko Haram, was charged with terrorism-related offenses, including alleged complicity in the activities of the group. Salkida's case was notable for its implications on freedom of the press and the relationship between journalism and national security. This case highlighted the tension between national security measures and freedom of expression, demonstrating the legal complexities in addressing terrorism while safeguarding civil liberties.

i. Federal Republic of Nigeria v. Tukur Mamu (2023): Tukur Mamu, a controversial figure and alleged financier of terrorism, was charged with various offenses related to the funding of terrorist activities. His case involved complex issues related to the financing of terrorism and the legal challenges of proving financial links to terrorist groups. Mamu's trial underscored the importance of combating terrorism financing and the need for effective legal mechanisms to trace and prosecute those who fund terrorist activities.

j. Federal Republic of Nigeria v. Aminu Sadiq Ogwuche (2015): Aminu Sadiq Ogwuche was involved in the 2014 Abuja bombing that killed over 70 people. His trial was significant for its focus on the legal process in terrorism cases and the application of the Terrorism (Prevention) Act. Ogwuche's case highlighted the judicial handling of complex terrorism cases and the procedural challenges in ensuring fair trials while addressing national security concerns.

These landmark cases illustrate the Nigerian judiciary's role in addressing terrorism, the application of anti-terrorism laws, and the balance between national security and individual rights. They reflect ongoing efforts to strengthen legal frameworks and ensure justice in the fight against terrorism. These cases collectively illustrate the evolving legal responses to cross-border security challenges in North-East Nigeria. They emphasize the importance of a robust legal framework, effective enforcement, and judicial oversight in addressing the complex security issues posed by terrorism and transnational crimes.

9. STRENGTHENING CROSS-BORDER LEGAL FRAMEWORKS

Nigeria's domestic legal frameworks, including counter-terrorism laws and humanitarian regulations, provide a foundation for addressing the crisis. However, their effectiveness is hampered by inconsistent implementation and challenges in coordinating with neighboring countries. The MNJTF, established by the Lake Chad Basin Commission, represents a key regional effort to combat insurgency. While it demonstrates regional cooperation, there are limitations in terms of legal harmonization and operational synergy among member states. International frameworks, such as the United Nations Security Council resolutions and humanitarian conventions, offer guidance on managing conflicts and protecting human rights. Their application in the North-East Nigerian context requires stronger integration with regional and national efforts.

10. FINDINGS

Despite the comprehensive nature of Nigeria's legal framework for addressing transnational security challenges, there are several notable lacunae (gaps or deficiencies) that can impact the effectiveness of these laws. Here are some of the key lacunae:

a. Resource Constraints: Many security agencies face resource limitations, including insufficient funding, equipment, and personnel, which can hinder their ability to effectively enforce laws and conduct operations. Capacity Building: There is often a lack of continuous training and professional development for law enforcement and security personnel, impacting their ability to handle sophisticated transnational threats.

b. Fragmented Efforts: Coordination between various security agencies, such as the Nigerian Police Force, the Department of State Services (DSS), and the Nigerian Customs Service, can be fragmented, leading to inefficiencies and gaps in addressing cross-border threats. Information Sharing: Challenges in timely and secure information sharing between national agencies and international partners can limit the effectiveness of security operations and intelligence gathering.

c. Overlapping Jurisdictions: There can be overlaps and inconsistencies in the jurisdictions and responsibilities of different agencies, leading to confusion and potential gaps in enforcement. Legal Framework Updates: Some laws may not be regularly updated to address emerging threats and technological advancements, such as cyber-terrorism and advanced smuggling techniques.

d. Balancing Security and Rights: The need to balance effective security measures with respect for human rights can be challenging. Overly stringent measures or practices may lead to human rights abuses or undermine public trust. Legal Protections: In some cases, legal protections for individuals suspected of involvement in transnational crimes may be inadequate, leading to potential abuses of power or wrongful detentions.

e. Slow Judicial Processes: The judicial system may be slow in processing cases related to transnational crimes, leading to delays in justice and potential issues with the prosecution of offenders. Evidence Collection: Gathering and presenting evidence in complex transnational crime cases can be challenging, particularly when dealing with international elements or sophisticated criminal networks.

f. Cybersecurity: Existing laws may not fully address the complexities of cyber-terrorism and cybercrime, which are increasingly significant in transnational security threats. Emerging Technologies: The rapid evolution of technology often outpaces legislative updates, leaving gaps in the legal framework for managing new forms of transnational crime and security threats.

g. Compliance with International Norms: There may be gaps in aligning national laws with international standards and best practices for combating transnational security challenges. International Cooperation: While there are frameworks for international cooperation, practical issues in implementing joint operations and mutual legal assistance can limit effectiveness.

h. Local Involvement: Insufficient involvement of local communities and grassroots organizations in security efforts can lead to a lack of local support and cooperation, which is crucial for effective border security and counter-terrorism measures.

11. RECOMMENDATION

The following are hereby recommended:

1. Harmonizing Legal Standards

To improve effectiveness, there is a need for harmonized legal standards across the region. This includes aligning counter-terrorism laws, humanitarian regulations, and human rights protections to ensure a cohesive response to security and humanitarian challenges.

2. Enhancing Intelligence Sharing

Strengthening mechanisms for intelligence sharing among national and regional security agencies can improve the coordination of counter-insurgency operations and prevent cross-border threats. Legal frameworks should facilitate the secure and efficient exchange of information.

3. Strengthening Humanitarian Legal Protections

Developing and implementing robust legal frameworks to protect displaced persons and address humanitarian needs is crucial. This includes ensuring compliance with international humanitarian laws and establishing effective mechanisms for humanitarian assistance.

4. Promoting Joint Research Initiatives

Collaborative research efforts involving academic institutions, international organizations, and local stakeholders can provide valuable insights into the conflict and humanitarian situation. Joint research can inform policy decisions and operational strategies.

Policy Recommendations

1. Short-Term Actions

i.   Establish cross-border legal coordination committees to address immediate gaps and enhance cooperation.
ii. Implement joint training programs for security and humanitarian personnel to ensure consistent application of legal standards.

2. Long-Term Strategies

i.   Develop a comprehensive regional legal framework that integrates national and international standards.
ii. Foster long-term partnerships between governments, regional bodies, and international organizations to ensure sustained collaborative efforts.

12. CONCLUSION

Strengthening cross-border legal frameworks is essential for effectively addressing the complex security and humanitarian challenges in North-East Nigeria. By promoting collaborative approaches, harmonizing legal standards, and enhancing operational coordination, stakeholders can achieve a more effective and unified response to the crisis. The recommendations aim to build a robust legal foundation for regional stability and humanitarian relief. However, the challenges include Resource Limitations: Effective enforcement of laws requires adequate resources, including personnel, technology, and funding. Limited resources can hinder the effectiveness of security operations. Capacity continuous training and capacity building are necessary to ensure that security personnel can effectively handle transnational security challenges. Effective cross-border security requires seamless coordination between different national agencies and international partners. Poor coordination can lead to gaps and inefficiencies. Timely and accurate information sharing between agencies and with international partners is crucial for addressing transnational threats. Challenges in this area can affect the overall effectiveness of security measures. Transnational security challenges are constantly evolving. Laws and frameworks must be adaptable to address new and emerging threats, such as cyber-terrorism and advanced smuggling techniques. Regular updates and amendments to laws are necessary to keep pace with changing security dynamics and technological advancements. Ensuring that security measures respect human rights are essential to maintaining public trust and legitimacy. Overly stringent measures can sometimes lead to human rights abuses and undermine the effectiveness of security operations.

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      i.   Description: Reports and publications from OCHA can provide insights into humanitarian challenges and responses in conflict-affected regions like North-East Nigeria.

[6].   International Crisis Group Reports (2020)
     ii.   Description: Provides detailed reports and analysis on conflict and security issues in Nigeria and West Africa.

A REVIEW OF THE EFFECT OF SOME PLANT BACTERIA ON GROUNDNUT PLANT IN NIGERIA

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ABSTRACT

Groundnut (Arachis hypogaea L.), a key leguminous crop, will continue to face challenges from soil-borne pathogens and environmental stressors that impact its growth and productivity. In recent years, plant-associated bacteria will emerge as promising biological control agents and growth enhancers in sustainable agriculture. This comprehensive review will elucidate the multifaceted effects of plant bacteria on groundnut plants, focusing on their roles in disease management and growth promotion. The review will delve into various classes of plant bacteria, including plant growth-promoting rhizobacteria (PGPR), mycorrhizal fungi, and biocontrol agents, evaluating their mechanisms of action and effectiveness. Key mechanisms will include nutrient solubilization, hormone production, and the induction of systemic resistance, all of which contribute to improved plant health and yield. Additionally, the review will explore how these bacteria suppress pathogenic microbes through competitive exclusion, antibiosis, and enzyme production. Recent studies will demonstrate that inoculation with specific bacterial strains will enhance groundnut growth parameters such as root development, nitrogen fixation, and overall biomass. Furthermore, these bacterial treatments will mitigate the impacts of various soil-borne diseases, including those caused by fungi, bacteria, and nematodes, thereby contributing to increased crop resilience. The review will also address practical aspects of integrating bacterial inoculants into groundnut cultivation, including formulation, application methods, and field performance. It will discuss the potential benefits and limitations of bacterial interventions, highlighting areas for future research to optimize their use and address challenges such as environmental variability and microbial interactions. Plant bacteria will represent a promising tool for enhancing groundnut health and productivity. The review will emphasize the need for continued research to refine bacterial applications and integrate them effectively into agricultural practices, aiming to advance sustainable crop management strategies and improve groundnut yields globally.

Keywords: Groundnut, Arachis hypogaea, plant growth-promoting rhizobacteria (PGPR), biocontrol agents, nutrient solubilization,

1.   Introduction

The groundnut, also known as peanut (Arachis hypogaea L.), is a significant crop with widespread cultivation across tropical and subtropical regions. Groundnut plants are valued for their edible seeds, which are rich in protein, oil, and essential nutrients. According to Smith et al. (2018), groundnuts are a major source of dietary protein in many developing countries and are crucial for food security. The plant's ability to grow in diverse environments and its relatively low input requirements make it an important crop for smallholder farmers in regions such as Africa, Asia, and Latin America (Osei et al., 2020). In addition to its nutritional benefits, groundnuts contribute significantly to the global economy, with millions of tons produced annually and a substantial trade volume impacting economies worldwide (FAO, 2021).

The role of plant bacteria in agriculture has garnered increasing attention due to their potential to enhance plant growth, improve soil health, and contribute to sustainable farming practices. Plant bacteria, including those involved in nitrogen fixation, phosphate solubilization, and disease suppression, interact with plants in various beneficial ways. Nitrogen-fixing bacteria, such as those belonging to the genus *Rhizobium*, form symbiotic relationships with leguminous plants, including groundnuts, to convert atmospheric nitrogen into a form usable by plants (Moulin et al., 2001). This symbiotic relationship is critical for groundnut plants, which rely on these bacteria to meet their nitrogen needs and achieve optimal growth (Giller, 2001).

Phosphate-solubilizing bacteria (PSB) also play a significant role in enhancing groundnut plant health. According to Rodriguez and Fraga (1999), these bacteria can convert insoluble phosphate compounds in the soil into forms that are readily available to plants, thus improving nutrient uptake and promoting better plant development. For groundnut plants, which often grow in phosphorus-deficient soils, the presence of PSB can substantially increase yield and nutrient content (Hayat et al., 2010). The effectiveness of these bacteria in solubilizing phosphate and enhancing plant growth has been demonstrated in various studies, highlighting their importance in sustainable agriculture (Khan et al., 2009).

In addition to enhancing nutrient availability, plant bacteria are crucial for disease management. Beneficial bacteria can suppress plant pathogens through mechanisms such as competition for resources, production of antimicrobial compounds, and induction of plant defense responses (Lugtenberg & Kamilova, 2009). For groundnuts, which are

susceptible to various bacterial and fungal diseases, the application of beneficial bacteria can reduce disease incidence and improve plant health (Mendes et al., 2013). For instance, *Bacillus subtilis* and *Pseudomonas fluorescens* have been identified as effective biocontrol agents for several groundnut pathogens, offering a viable alternative to chemical pesticides (Compant et al., 2019).

1.2   Major Producers of Groundnut in Nigeria

Nigeria is one of the leading producers of groundnut in Africa, with several states contributing significantly to its production. The primary groundnut-producing regions include:

1. **Kano State**: Located in the northern part of Nigeria, Kano is renowned for its large-scale groundnut cultivation. The state's favorable climate and soil conditions make it ideal for groundnut farming.

2. **Sokoto State**: Another major producer in the northwest, Sokoto has substantial groundnut farming activities. The state benefits from extensive arable land and traditional agricultural practices.

3. **Kaduna State**: Situated in the north-central region, Kaduna is also a key player in groundnut production. The state's agriculture sector is diverse, with groundnut being a significant crop.

4. **Zamfara State**: Known for its agricultural output, Zamfara contributes notably to groundnut production. The state's agricultural landscape supports various crops, including groundnut.

5. **Jigawa State**: Located in the northwest, Jigawa is an important groundnut-producing area. The state's agricultural practices support the cultivation of this crop alongside others.

Groundnut, commonly known as peanut (Arachis hypogaea L.), is a crucial crop in global agriculture, valued not only for its nutritional benefits but also for its economic importance. As an essential source of protein, oil, and various nutrients, groundnut plays a significant role in the diets of many populations and contributes to food security, especially in developing countries. The crop is particularly important in tropical and subtropical regions, where it is grown extensively due to its adaptability to diverse soil types and climates (Kumar et al., 2018).

Groundnut cultivation is characterized by its dual role in providing economic value and supporting sustainable farming practices. The crop's ability to fix atmospheric nitrogen through symbiotic relationships with soil bacteria, such as *Rhizobium* spp., enhances soil fertility and reduces the need for synthetic fertilizers (Sanginga & Woomer, 2009). This characteristic not only contributes to the economic viability of groundnut farming but also aligns with broader goals of sustainable agriculture by minimizing environmental impacts associated with chemical inputs (Ladha et al., 2016).

In recent years, there has been growing interest in the role of plant-associated bacteria in enhancing crop productivity and soil health. Plant bacteria, including nitrogen-fixing and phosphate-solubilizing bacteria, interact with groundnut plants in complex ways that can influence various aspects of growth and development. These interactions can improve seed germination, root development, and overall plant health (Glick, 2012). For instance, the introduction of beneficial bacteria into the soil can lead to increased nutrient availability, which is crucial for groundnut plants that are sensitive to nutrient deficiencies (Khan et al., 2009).

Furthermore, the impact of plant bacteria extends to disease management. Beneficial bacteria can act as biocontrol agents, suppressing the growth of pathogenic organisms that threaten groundnut crops. The use of these bacteria offers a sustainable alternative to chemical pesticides, which can have adverse environmental and health effects (Kloepper et al., 2004). By promoting plant health and suppressing diseases, plant bacteria contribute to more resilient and productive groundnut farming systems.

Despite the promising benefits, the adoption of plant bacteria in groundnut cultivation faces several challenges. These include variability in bacterial efficacy across different soil types and environmental conditions, as well as the need for standardized application methods (Lugtenberg & Kamilova, 2009). Additionally, there is a need for more comprehensive studies on the long-term effects of bacterial inoculants on soil health and crop productivity (Giller, 2001). Addressing these challenges requires a multidisciplinary approach, integrating advances in microbiology, agronomy, and environmental science to optimize the use of plant bacteria in agriculture.

The interplay between plant bacteria and groundnut plants is complex and multifaceted, involving interactions that impact growth, nutrient uptake, and disease resistance. The integration of beneficial bacteria into groundnut cultivation practices presents a promising avenue for enhancing agricultural productivity and sustainability. Research on plant-bacteria interactions continues to reveal new insights into how these microorganisms can be harnessed to support groundnut cultivation and address the challenges faced by farmers in different regions (Van der Heijden et al., 2008; Santoyo et al., 2017). Understanding these interactions is critical for developing effective strategies to optimize groundnut production and promote sustainable agricultural practices.

1.3 Aim and Objectives of the Study

The aim of this study is to critically evaluate the effects of plant bacteria on groundnut (peanut) plants, focusing on how these microorganisms influence growth, yield, disease resistance, and soil health. The study seeks to understand the role of plant bacteria in enhancing groundnut cultivation and to identify potential benefits and limitations associated with their use.

The specific objectives of the study are:

i. To assess the impact of beneficial plant bacteria on groundnut seed germination and early growth stages.

ii. To evaluate how plant bacteria affect nutrient uptake and overall plant health in groundnut.

iii. To investigate the role of plant bacteria in disease suppression and management in groundnut crops.

iv. To examine the influence of plant bacteria on soil fertility and microbial diversity in the rhizosphere of groundnut plants.

v. To identify the mechanisms through which plant bacteria contribute to improved groundnut productivity and sustainability.

1.4   Scope of the Study

The scope of the study encompasses the interactions between plant bacteria and groundnut plants within various agricultural settings. It will cover a range of aspects including seed germination, plant growth, nutrient uptake, disease management, and soil health. The study will focus on several types of plant bacteria known to have beneficial effects on legumes, with a particular emphasis on their impact on groundnut cultivation. Geographically, the study will consider both controlled experimental environments and field trials from different regions where groundnut is commonly grown. The investigation will also explore the application methods of plant bacteria and their effectiveness in real-world agricultural practices.

1.5   Significance of the Study

This study holds significant implications for both agricultural practice and research. Understanding the effects of plant bacteria on groundnut plants can lead to improved cultivation techniques that enhance yield and sustainability. By identifying effective bacterial strains and their mechanisms of action, the study can provide valuable insights for developing bio-inoculants that support groundnut growth and resilience. This has the potential to benefit farmers by reducing the need for chemical fertilizers and pesticides, thus promoting environmentally friendly agricultural practices. Furthermore, the study's findings can contribute to the broader field of soil microbiology and plant-microbe interactions, offering new knowledge on how beneficial bacteria can be harnessed to optimize crop production. The research may also inform policy and decision-making related to sustainable agriculture and food security. Ultimately, the study aims to advance scientific understanding and practical applications of plant bacteria in enhancing groundnut production and supporting global food systems.

2.0   LITERATURE REVIEW
2.1   Plant Bacteria: An Overview

Plant bacteria, also known as plant-associated bacteria, are microorganisms that reside in or around plant roots and play critical roles in plant health and growth. These bacteria can be broadly classified into various categories based on their interactions with plants and their functions. According to Berg et al. (2014), plant bacteria can be divided into three primary groups: beneficial bacteria, pathogenic bacteria, and symbiotic bacteria. Beneficial bacteria promote plant growth, enhance nutrient availability, and protect plants from diseases. Pathogenic bacteria cause diseases and negatively impact plant health, while symbiotic bacteria establish mutualistic relationships with plants, providing essential nutrients in exchange for carbohydrates.

Beneficial plant bacteria are particularly relevant to groundnut (peanut) plants. Among the most significant types are nitrogen-fixing bacteria, phosphate-solubilizing bacteria, and plant growth-promoting rhizobacteria (PGPR). Nitrogen-fixing bacteria, such as *Rhizobium* spp., form symbiotic relationships with leguminous plants like groundnuts to convert atmospheric nitrogen into a form usable by plants (Giller, 2001). This symbiosis is crucial for groundnut plants, which rely heavily on nitrogen for growth and development. The effectiveness of these bacteria in nitrogen fixation has been well-documented, with studies highlighting their role in improving soil fertility and plant productivity (Moulin et al., 2001; Sturz & Nowak, 2000).

Phosphate-solubilizing bacteria (PSB) are another important group. These bacteria, including *Bacillus* spp. and *Pseudomonas* spp., are capable of converting insoluble phosphate compounds in the soil into forms that plants can readily absorb (Rodriguez & Fraga, 1999). For groundnut plants, which often grow in phosphorus-deficient soils, the presence of PSB can significantly enhance nutrient availability, leading to improved growth and yield (Khan et al., 2009; Hayat et al., 2010). The role of PSB in promoting plant health and productivity has been extensively studied, showing their potential in sustainable agriculture practices.

Plant growth-promoting rhizobacteria (PGPR) are a diverse group of bacteria that positively influence plant growth through various mechanisms. These include the production of plant growth-promoting hormones, such as indole-3-acetic acid (IAA), and the suppression of plant pathogens (Lugtenberg & Kamilova, 2009). PGPR can also enhance root development and increase resistance to environmental stresses, which is beneficial for groundnut plants (Kloepper et al., 1989). The mechanisms through which PGPR promote plant growth are complex and involve interactions with the plant's root system and surrounding soil environment.

The mechanisms of plant-bacteria interactions involve a range of biochemical and physiological processes. Beneficial bacteria can influence plant growth by synthesizing growth-promoting substances, such as auxins, cytokinins, and gibberellins, which stimulate root elongation and increase nutrient uptake (Pineda et al., 2017). Additionally, some bacteria produce siderophores, which chelate iron and make it available to plants, enhancing growth in iron-deficient soils (Hider & Kong, 2010). Pathogenic bacteria, on the other hand, employ various strategies to invade and cause disease, including the production of virulence factors and the manipulation of plant immune responses (Schulze-Lefert & Panstruga, 2011).

2   Impact of Plant Bacteria on Groundnut Growth

The interaction between plant bacteria and groundnut plants significantly influences various growth parameters, including seed germination, root development, and overall plant biomass. The effects of plant bacteria on these aspects have been extensively studied, revealing both direct and indirect impacts on groundnut growth.

3   Effects on Seed Germination

Seed germination is a critical phase in plant development, determining the initial growth and establishment of groundnut plants. Plant bacteria, particularly those classified as plant growth-promoting rhizobacteria (PGPR), have been shown to enhance seed germination rates and seedling vigor. According to a study by Muthukumarasamy et al. (2008), inoculation with *Bacillus* spp. and *Pseudomonas* spp. significantly improved germination rates in groundnut seeds compared to untreated controls. These bacteria may produce growth-promoting substances such as indole-3-acetic acid (IAA) or affect the availability of essential nutrients, thereby accelerating the germination process (Khan et al., 2009). The ability of plant bacteria to enhance seed germination can lead to more uniform and robust plant stands, which are essential for achieving high yields.

4   Influence on Root Development

Root development is crucial for nutrient and water uptake, as well as for anchoring the plant in the soil. Beneficial plant bacteria can positively influence root growth and development in groundnut plants. For example, nitrogen-fixing bacteria such as *Rhizobium* spp. establish symbiotic relationships with leguminous plants, including groundnuts, to enhance root development and increase nitrogen availability (Giller, 2001). This interaction not only supports better root architecture but also improves overall plant health by ensuring adequate nutrient supply. Furthermore, phosphate-solubilizing bacteria (PSB) such as *Bacillus* spp. enhance root growth by making phosphorus more available in the soil, which is vital for root development and function (Rodriguez & Fraga, 1999). Enhanced root systems facilitated by these bacteria lead to improved water and nutrient uptake, ultimately benefiting plant growth.

5   Impact on Plant Growth and Biomass

The overall growth and biomass accumulation of groundnut plants are influenced by the presence and activity of beneficial plant bacteria. Studies have demonstrated that the application of PGPR can lead to increased plant growth, including enhanced shoot and root biomass. For instance, research by Babalola (2010) showed that groundnut plants inoculated with PGPR had significantly higher shoot biomass and improved growth parameters compared to non-inoculated plants. These bacteria can produce growth-promoting hormones and improve nutrient availability, which

contributes to increased plant biomass and overall productivity (Glick, 2012). Additionally, the role of plant bacteria in enhancing stress resistance further contributes to better growth outcomes under adverse conditions (Kloepper et al., 1989).

6 Beneficial Plant Bacteria and Their Mechanisms

Nitrogen-fixing bacteria are integral to the nitrogen cycle in agriculture, particularly for leguminous plants like groundnuts (Arachis hypogaea). These bacteria, primarily of the genera *Rhizobium*, *Bradyrhizobium*, and *Sinorhizobium*, form symbiotic relationships with the plant's root system. In this mutualistic interaction, the bacteria colonize the root nodules of leguminous plants, where they convert atmospheric nitrogen (N_2) into ammonia (NH_3), a form of nitrogen that plants can readily use (Giller, 2001). This process, known as biological nitrogen fixation, is crucial because atmospheric nitrogen is inaccessible to plants in its diatomic form.

The efficiency of nitrogen fixation and its contribution to plant growth have been widely documented. According to a study by Smith et al. (2018), the symbiosis between *Rhizobium* and groundnut plants significantly enhances nitrogen availability, leading to improved plant growth and yield. The bacteria produce an enzyme called nitrogenase, which catalyzes the conversion of N_2 to NH_3 within the root nodules (Berg et al., 2014). This process not only provides essential nitrogen for plant development but also reduces the need for synthetic nitrogen fertilizers, promoting sustainable agricultural practices.

7 Phosphate-Solubilizing Bacteria and Their Effect on Nutrient Availability

Phosphate-solubilizing bacteria (PSB) play a critical role in enhancing soil phosphorus availability, which is vital for plant growth. Phosphorus is a key nutrient involved in energy transfer, photosynthesis, and root development, but it is often present in soils in forms that are not readily available to plants (Rodriguez & Fraga, 1999). PSB, including genera such as *Bacillus*, *Pseudomonas*, and *Burkholderia*, have the ability to solubilize insoluble phosphate compounds in the soil, converting them into soluble forms that can be absorbed by plant roots (Khan et al., 2009).

Studies have demonstrated that inoculation with PSB can significantly improve phosphorus uptake by plants, leading to enhanced growth and yield. For example, Hayat et al. (2010) reported that groundnut plants inoculated with phosphate-solubilizing bacteria exhibited increased phosphorus content in their tissues, resulting in better overall plant health and productivity. The solubilization of phosphorus by these bacteria involves the production of organic acids, such as citric and gluconic acids, which dissolve phosphate minerals and make phosphorus available to plants (Rodriguez & Fraga, 1999).

8 Production of Plant Growth-Promoting Hormones

Plant growth-promoting rhizobacteria (PGPR) contribute to plant growth through the production of various growth-promoting hormones. These hormones include indole-3-acetic acid (IAA), gibberellins, and cytokinins, which play crucial roles in regulating plant growth and development (Pineda et al., 2017). IAA, a type of auxin, is particularly important for root elongation, cell division, and differentiation. Bacteria such as *Bacillus subtilis* and *Pseudomonas fluorescens* are known to produce IAA, which enhances root development and increases the plant's ability to absorb nutrients and water (Kloepper et al., 2004).

Gibberellins and cytokinins produced by PGPR can further enhance plant growth by promoting stem elongation, leaf expansion, and overall biomass accumulation. For instance, research by Glick (2012) highlights the role of these hormones in improving plant responses to environmental stresses and enhancing nutrient uptake. The application of PGPR that produces these hormones has been shown to result in healthier and more vigorous plants, as demonstrated in various studies on groundnuts and other crops (Compant et al., 2019).

9 Disease Management and Plant Bacteria

Groundnut (peanut) plants are susceptible to several bacterial diseases that can significantly impact their health and productivity. Among the most common bacterial diseases affecting groundnut crops are bacterial wilt, caused by *Ralstonia solanacearum*, and bacterial blight, caused by *Xanthomonas axonopodis* pv. *arachidis* (Denny, 2006; Mew, 2007). Bacterial wilt, a soil-borne disease, leads to wilting, yellowing, and ultimately the death of the plant by infecting

the vascular tissues and disrupting water and nutrient transport (Hayward, 1991). Bacterial blight, on the other hand, causes leaf spots and lesions, which reduce photosynthesis and can lead to significant yield losses if not managed effectively.

In addition to these major diseases, groundnut plants can also be affected by other bacterial pathogens that cause various symptoms such as root rot, pod blight, and bacterial leaf spot (Henderson et al., 1998). Effective management of these diseases is crucial for maintaining groundnut productivity and minimizing economic losses in affected regions.

10   Biocontrol Potential of Beneficial Bacteria

Beneficial plant bacteria, particularly those classified as plant growth-promoting rhizobacteria (PGPR), have shown significant potential as biocontrol agents against various plant diseases, including those affecting groundnuts. PGPR can suppress the growth of plant pathogens through several mechanisms, including competition for resources, production of antimicrobial compounds, and induction of systemic resistance in plants (Glick, 2012; Kloepper et al., 2004). For instance, *Pseudomonas fluorescens* and *Bacillus subtilis* are well-documented for their ability to produce antibiotics and other bioactive compounds that inhibit the growth of pathogenic bacteria (Lugtenberg & Kamilova, 2009).

Research has demonstrated the efficacy of these beneficial bacteria in controlling bacterial diseases in groundnut crops. A study by Nair et al. (2006) found that soil application of *Bacillus* spp. significantly reduced the incidence of bacterial wilt in groundnuts by outcompeting pathogenic bacteria for nutrients and space in the rhizosphere. Similarly, *Pseudomonas* spp. have been shown to induce systemic resistance in plants, enhancing their ability to withstand bacterial infections (Kloepper et al., 2004).

11   Mechanisms of Disease Suppression

The mechanisms through which beneficial bacteria suppress plant diseases are diverse and involve both direct and indirect methods. Direct mechanisms include the production of antimicrobial substances such as antibiotics, lytic enzymes, and hydrogen cyanide, which inhibit pathogen growth (Lugtenberg & Kamilova, 2009). For example, *Pseudomonas fluorescens* produces a range of antifungal and antibacterial compounds that can suppress the growth of pathogenic bacteria and fungi (Weller et al., 2002).

Indirect mechanisms involve the stimulation of the plant's own defense responses. Beneficial bacteria can induce systemic acquired resistance (SAR) or induced systemic resistance (ISR) in plants. These resistance mechanisms involve the activation of the plant's immune system, leading to enhanced resistance against a broad spectrum of pathogens (Pieterse et al., 2014). Additionally, beneficial bacteria can improve plant health by enhancing nutrient availability, thereby reducing the susceptibility of plants to diseases (Glick, 2012).

12   Soil Health and Plant Bacteria

Plant bacteria play a crucial role in enhancing soil quality and structure, which are essential for promoting healthy plant growth. Beneficial bacteria, such as those belonging to the genera *Bacillus*, *Pseudomonas*, and *Rhizobium*, contribute to soil improvement through various mechanisms. These bacteria can improve soil structure by producing extracellular polysaccharides that help aggregate soil particles, thereby enhancing soil aeration and water infiltration (Jeffries et al., 2003). Aggregated soil is less prone to erosion and compaction, which helps maintain optimal conditions for root growth and nutrient uptake.

Additionally, plant bacteria contribute to the stabilization of soil aggregates. According to a study by Archaea et al. (2016), the presence of beneficial bacteria can enhance soil aggregation by promoting the formation of stable soil aggregates through the secretion of mucilaginous substances. This process not only improves soil structure but also reduces soil erosion and increases the soil's ability to retain moisture, which is critical for sustaining plant growth during dry periods.

13   Interaction with Soil Microbial Communities

The interaction between plant bacteria and other soil microbial communities is a key factor in maintaining soil health and fertility. Plant bacteria, particularly those classified as plant growth-promoting rhizobacteria (PGPR), can influence the composition and activity of the broader soil microbial community. These interactions can lead to increased microbial diversity and functionality in the soil (Lugtenberg & Kamilova, 2009).

For instance, PGPR can produce antibiotics and other antimicrobial compounds that suppress harmful pathogens, thereby creating a more favorable environment for beneficial microorganisms. Research by Berendsen et al. (2012) highlighted that the introduction of beneficial bacteria to the soil can shift microbial community structures in ways that enhance soil health and plant growth. This shift often results in a more balanced microbial ecosystem, which supports the breakdown of organic matter and the recycling of nutrients.

Moreover, plant bacteria can enhance the activity of mycorrhizal fungi, which form symbiotic relationships with plant roots. These fungi are critical for nutrient uptake, particularly phosphorus, and their activity is often stimulated by the presence of beneficial bacteria (Glick, 2012). The synergy between bacteria and mycorrhizal fungi can lead to improved soil fertility and plant health by increasing the availability of essential nutrients.

14   Impact on Soil Fertility and Plant Health

The impact of plant bacteria on soil fertility and plant health is significant and multifaceted. Beneficial bacteria contribute to soil fertility through several mechanisms, including nitrogen fixation, phosphate solubilization, and the decomposition of organic matter. Nitrogen-fixing bacteria, such as those of the *Rhizobium* genus, enhance soil fertility by converting atmospheric nitrogen into a form usable by plants, reducing the need for synthetic fertilizers (Giller, 2001). Phosphate-solubilizing bacteria, such as *Bacillus* spp., make phosphorus more available in the soil, which is crucial for plant growth and development (Rodriguez & Fraga, 1999).

Furthermore, the decomposition of organic matter by plant bacteria contributes to the formation of humus, which improves soil structure, water-holding capacity, and nutrient availability. Studies have shown that soil inoculation with beneficial bacteria can lead to increased soil organic matter content and enhanced soil fertility (Khan et al., 2009). For example, research by Hayat et al. (2010) demonstrated that the application of PGPR to soil resulted in improved soil properties and increased plant growth, underscoring the role of these bacteria in supporting sustainable agricultural practices.

In summary, plant bacteria play a vital role in maintaining and improving soil health through their effects on soil quality and structure, interactions with soil microbial communities, and impacts on soil fertility and plant health. By enhancing soil conditions and promoting beneficial microbial interactions, these bacteria contribute to more resilient and productive agricultural systems.

2.2   Properties of Groundnut

Groundnut (Arachis hypogaea L.), commonly known as peanut, possesses several notable properties that make it an important agricultural crop and a valuable food resource. Here's an in-depth discussion on the properties of groundnut:

1. Nutritional Properties

a. Protein Content: Groundnut is rich in protein, containing approximately 25-30% protein by weight. This makes it a crucial source of plant-based protein, particularly in regions where animal protein is less accessible.

b. Fat Content: Groundnuts have a high fat content, about 40-50% of their weight, primarily composed of unsaturated fats. These include monounsaturated and polyunsaturated fatty acids, which are beneficial for cardiovascular health.

c. Carbohydrates: Groundnuts also contain a significant amount of carbohydrates, roughly 10-20%, which provide energy. The carbohydrate content includes both simple sugars and complex carbohydrates.

d. Vitamins and Minerals: Groundnuts are a good source of several vitamins, including vitamin E (an antioxidant), B vitamins (such as niacin, folate, and thiamine), and minerals like magnesium, phosphorus, potassium, and zinc. These nutrients are essential for various physiological functions and overall health.

e. Dietary Fiber: They contain dietary fiber, which aids in digestive health and can help regulate blood sugar levels and cholesterol.

2. Agronomic Properties

a. Growth Habit: Groundnut is a leguminous plant with a unique growth habit. It is an annual herbaceous plant that develops underground pods after flowering. The plant typically grows to about 30-50 cm in height.

b. Soil and Climate Adaptability: Groundnuts are adaptable to a range of soil types but prefer well-drained, sandy loam soils. They thrive in warm climates with temperatures ranging from 20°C to 30°C. The crop requires a moderate amount of rainfall or irrigation during its growing season.

c. Nitrogen Fixation: As a legume, groundnuts have the ability to fix atmospheric nitrogen into the soil through a symbiotic relationship with rhizobial bacteria. This improves soil fertility and reduces the need for synthetic nitrogen fertilizers.

3. Chemical Properties

a. Oil Composition: The oil extracted from groundnuts is high in unsaturated fatty acids, including oleic acid and linoleic acid. This composition makes it a valuable ingredient in cooking and food processing due to its stability and health benefits.

b. Antioxidants: Groundnuts contain various antioxidants, including resveratrol and flavonoids, which help in combating oxidative stress and reducing inflammation.

c. Aflatoxins: Groundnuts are susceptible to contamination by aflatoxins, which are toxic compounds produced by certain molds. Proper handling and storage are crucial to minimize aflatoxin contamination and ensure food safety.

4. Economic and Cultural Significance

a. Economic Value: Groundnut is a major cash crop in many countries, contributing significantly to the agricultural economy. It is used for various purposes, including oil extraction, confectionery, and as a food ingredient in many cuisines.

b. Cultural Importance: In many cultures, groundnuts play a significant role in traditional dishes and recipes. They are often used in cooking, baking, and as snacks.

5. Health Benefits

a. Cardiovascular Health: The high content of unsaturated fats and antioxidants in groundnuts supports heart health by improving lipid profiles and reducing the risk of heart disease.

b. Weight Management: Despite being calorie-dense, groundnuts can aid in weight management due to their high protein and fiber content, which can promote satiety and reduce overall calorie intake.

c. Blood Sugar Control: The presence of fiber and healthy fats can help in moderating blood sugar levels, making groundnuts a beneficial food for managing diabetes.

Infected groundnut (Arachis hypogaea L.), commonly known as peanuts, is a significant issue in agriculture that can impact yield, quality, and economic viability. Infection in groundnuts can be caused by a range of pathogens, including fungi, bacteria, viruses, and nematodes. Understanding the causes, effects, and management strategies for infected groundnut is crucial for maintaining healthy crops and ensuring sustainable production.

1. Causes of Infection in Groundnut

a. Fungal Pathogens: Fungi are among the most common pathogens affecting groundnut crops. Major fungal diseases include:

- **Early Blight (Cercospora arachidicola)**: Characterized by dark, sunken lesions on leaves, leading to premature leaf drop and reduced photosynthesis.

- **Late Blight (Alternaria arachidis)**: Causes dark, irregular lesions on leaves and pods, impacting overall plant health.

- **Leaf Spot (Cercospora personata)**: Leads to small, dark spots on leaves, which can coalesce and cause significant defoliation.

- **Root Rot (Fusarium spp., Rhizoctonia solani)**: Affects the root system, causing rot and poor nutrient uptake.

b. Bacterial Pathogens: Bacterial infections can also impact groundnut health. Notable bacterial diseases include:
- **Bacterial Wilt (Ralstonia solanacearum)**: Causes wilting and yellowing of leaves, often leading to plant death.

- **Crown Rot (Pseudomonas spp.)**: Affects the crown of the plant, leading to stunted growth and reduced yield.

c. Viral Pathogens: Viruses can cause various symptoms in groundnuts, including:
- **Groundnut Rosette Virus (GRV)**: Causes leaf distortion, chlorosis, and stunted growth, severely affecting yield.

- **Peanut Mottle Virus (PMV)**: Leads to mottling of leaves, stunted growth, and reduced pod development.

d. Nematodes: Soil-dwelling nematodes can infest the roots of groundnut plants, causing damage such as:
- **Root-Knot Nematodes (Meloidogyne spp.)**: Cause galls on roots, impairing nutrient and water uptake and leading to reduced plant vigor.

2. Effects of Infection on Groundnut

a. Reduced Yield: Infections often lead to lower yields due to reduced pod development and poor plant health. Yield losses can be significant, affecting both the quantity and quality of the harvested groundnuts.

b. Poor Quality: Infected groundnuts may exhibit poor seed quality, including irregular shapes, discoloration, and reduced oil content. This can affect their market value and suitability for processing.

c. Economic Impact: The financial losses incurred from reduced yields and quality can be substantial for farmers. Additional costs may include expenses for disease management, such as purchasing fungicides or other treatments.

d. Soil Health: Persistent infections can impact soil health, particularly if pathogens are soil-borne. This can lead to a cycle of infection affecting future crops and reducing soil fertility.

3. Management Strategies for Infected Groundnut

a. Resistant Varieties: Planting groundnut varieties that are resistant or tolerant to specific pathogens can be an effective strategy for managing infections. Research and development of disease-resistant cultivars are crucial.

b. Crop Rotation: Rotating groundnuts with non-leguminous crops can help break the life cycle of soil-borne pathogens and reduce their prevalence.

c. Soil Management: Improving soil health through practices such as organic matter addition, proper drainage, and maintaining soil pH can help reduce pathogen load and improve plant resilience.

d. Fungicide and Bactericide Application: Applying appropriate fungicides and bactericides can help control fungal and bacterial diseases. It is important to use these chemicals judiciously and follow recommended application rates to avoid resistance development.

e. Biological Control: Utilizing beneficial microbes, such as certain bacteria and fungi, can help suppress pathogenic organisms. For example, certain strains of *Bacillus* and *Trichoderma* have shown potential in controlling soil-borne diseases.

f. Good Agricultural Practices (GAP): Implementing practices such as proper planting density, regular weeding, and timely harvesting can reduce the incidence of infections and improve overall plant health.

g. Monitoring and Early Detection: Regular monitoring of crops for symptoms of infection and early detection can help in implementing timely management strategies and preventing the spread of diseases.

h. Integrated Pest Management (IPM): Combining various management approaches, including cultural, biological, and chemical methods, can provide a comprehensive strategy for managing groundnut infections.

4. Prevention and Future Directions

a. Education and Training: Educating farmers about disease identification, management strategies, and preventive measures is crucial for effective disease management.

b. Research and Innovation: Continued research into disease-resistant varieties, improved diagnostic tools, and innovative management practices will contribute to better control of infections in groundnuts.

c. Policy and Support: Supporting policies that promote research, extension services, and access to disease management resources can help farmers manage groundnut infections more effectively.

No	Pest/Disease	Plant Part Attacked	Causing Agent	Illustration
1	Wilt Disease	Root and Entire Plant Die	*Pythium* spp	
2	White Mold	Leaves	*Oidium* spp (putative)	
3	Rust Disease	Leaves	To be Determined	
4	Virus	Leaves	To be Determined	
5	Millipede Attack	Pods	*Myriapoda* spp	
6	Grasshopper Attack	Leaves	*Locustra* spp	
7	Caterpillar Attack	Leaves	*Lepidoptera*	

Fig 6: Life Cycle

2.3   Empirical Review

A study by Liu et al. (2017) titled "Effects of Plant Growth-Promoting Rhizobacteria on Groundnut Yield and Quality" employed a randomized controlled trial design to assess the impact of PGPR on groundnut plants. The population included groundnut farms in Yunnan Province, China, with a sample size of 120 farms selected using stratified random sampling. Data were validated through soil and plant tissue analyses. Reliability was ensured with a Cronbach's alpha of 0.89. Findings indicated that PGPR treatment improved groundnut yield by 25% and enhanced seed quality. The study recommended the widespread adoption of PGPR for improving groundnut production.

Smith et al. (2018) conducted research titled "The Role of Soil Microbial Communities in Enhancing Groundnut Resistance to Diseases" using a case-control design. The study targeted groundnut fields affected by bacterial wilt and used a sample of 50 fields selected through purposive sampling. Data validation involved microbial community profiling and disease incidence tracking. The reliability coefficient was 0.85. Results showed that diverse microbial communities significantly reduced disease incidence. Recommendations included the promotion of microbial community diversity in disease management practices.

In the study "Impact of Rhizobial Inoculation on Groundnut Growth and Soil Fertility" by Jain and Singh (2019), a longitudinal design was used with a population of groundnut fields in Rajasthan, India. A sample of 80 fields was selected using systematic sampling. Data validation was performed through regular soil testing and plant growth assessments, with a reliability coefficient of 0.88. The study found that rhizobial inoculation improved soil nitrogen levels and enhanced plant growth. It was recommended to use rhizobial inoculants as a standard practice for soil fertility management.

The research by Wang et al. (2020), "Evaluation of Phosphate-Solubilizing Bacteria on Groundnut Yield and Soil Health," used an experimental design with a population of groundnut farms in Shandong Province, China. A sample of 100 farms was chosen using random sampling. Data validation included soil and plant analyses, with a reliability score of 0.90. The study reported that phosphate-solubilizing bacteria increased soil phosphorus availability and groundnut yield. Recommendations included integrating these bacteria into soil management practices to enhance crop productivity.

In "Effects of Plant Growth-Promoting Rhizobacteria on Groundnut Disease Suppression" by Thomas et al. (2021), a cross-sectional design was employed. The population was groundnut fields affected by various diseases in Kenya, with a sample of 60 fields selected using stratified sampling. Data validation was achieved through disease assessment and bacterial population counts, with a reliability coefficient of 0.87. The findings indicated significant disease suppression with PGPR application. The study recommended the use of PGPR for integrated disease management in groundnut cultivation.

The study "Impact of Beneficial Bacteria on Groundnut Root Development" by Patel and Sharma (2022) utilized a comparative design with a population of groundnut farms in Gujarat, India. A sample of 90 farms was selected through random sampling. Data validation involved root growth measurements and bacterial population analysis, with a reliability score of 0.86. Results demonstrated enhanced root development with beneficial bacteria. The study recommended incorporating these bacteria into agricultural practices to improve root health and crop productivity.

In "Effectiveness of Biocontrol Agents in Managing Groundnut Bacterial Diseases" by Chandra et al. (2023), a field trial design was used with a population of groundnut fields in Tamil Nadu, India. The sample consisted of 70 fields selected using purposive sampling. Data validation was performed through biocontrol efficacy testing and disease incidence records, with a reliability coefficient of 0.89. The study found that biocontrol agents significantly reduced bacterial disease incidence. Recommendations included the adoption of biocontrol methods for sustainable disease management.

The research "Soil Health Improvement through Plant Bacteria Application in Groundnut Cultivation" by Nguyen and Lee (2024) used a randomized block design. The population included groundnut farms in Vietnam, with a sample of 85 farms selected using stratified sampling. Data validation was achieved through soil health assessments and plant growth evaluations, with a reliability score of 0.90. The study concluded that plant bacteria improved soil health and groundnut yield. Recommendations emphasized the integration of plant bacteria into soil management strategies.

In "Influence of Plant-Bacteria Interactions on Groundnut Growth and Soil Fertility" by Kumar et al. (2021), an experimental design was employed with a population of groundnut fields in Punjab, India. A sample of 75 fields was chosen through random sampling. Data validation involved soil fertility tests and plant growth measurements, with a reliability coefficient of 0.88. The findings indicated positive effects of plant-bacteria interactions on soil fertility and plant growth. The study recommended incorporating plant bacteria into groundnut cultivation practices to enhance soil and crop health.

The study "Role of Plant Bacteria in Enhancing Groundnut Yield and Quality" by Zhang and Liu (2020) used a case-study design with a population of groundnut farms in Sichuan, China. A sample of 100 farms was selected through

stratified sampling. Data validation included yield and quality assessments, with a reliability score of 0.87. Results showed significant improvements in both yield and quality with plant bacteria application. Recommendations included the adoption of plant bacteria as a standard practice for improving groundnut production.

In "Impact of Beneficial Bacteria on Groundnut Soil Health and Disease Resistance" by Mohamed and Ahmed (2021), a longitudinal study design was used with a population of groundnut fields in Sudan. A sample of 80 fields was selected using systematic sampling. Data validation involved soil health and disease resistance assessments, with a reliability coefficient of 0.85. The study found that beneficial bacteria improved soil health and increased disease resistance. Recommendations emphasized the use of beneficial bacteria for sustainable groundnut farming.

The research "Effect of Soil-Borne Bacteria on Groundnut Growth and Disease Management" by Adebayo and Adeoye (2022) utilized a field experiment design. The population included groundnut farms in Nigeria, with a sample of 60 farms selected through purposive sampling. Data validation was conducted through growth assessments and disease monitoring, with a reliability score of 0.88. Findings indicated that soil-borne bacteria positively affected growth and disease management. Recommendations included integrating these bacteria into soil management practices.

The study "Effectiveness of Plant Growth-Promoting Rhizobacteria on Groundnut Yield and Disease Resistance" by Reddy and Rao (2023) used a controlled trial design. The population comprised groundnut farms in Andhra Pradesh, India, with a sample of 70 farms selected using random sampling. Data validation was performed through yield and disease resistance testing, with a reliability coefficient of 0.86. Results showed enhanced yield and disease resistance with rhizobacteria. Recommendations included the use of rhizobacteria for improved groundnut farming outcomes.

In "Assessment of Plant Bacteria for Groundnut Disease Management and Soil Health" by Singh and Verma (2024), a survey design was used with a population of groundnut fields in Uttar Pradesh, India. A sample of 90 fields was selected through stratified sampling. Data validation involved disease assessments and soil health evaluations, with a reliability score of 0.87. The study found that plant bacteria improved disease management and soil health. Recommendations included the incorporation of plant bacteria into disease management strategies.

The research "Impact of Plant-Bacteria Interactions on Groundnut Productivity and Soil Fertility" by Liu and Zhang (2023) utilized an experimental design. The population was groundnut farms in Jiangsu, China, with a sample of 80 farms selected through purposive sampling. Data validation was achieved through productivity and soil fertility tests, with a reliability coefficient of 0.89. Findings indicated that plant-bacteria interactions enhanced productivity and soil fertility. Recommendations focused on integrating these interactions into groundnut cultivation practices for better results.

The study "Role of Rhizobial Inoculation in Improving Groundnut Soil Health and Yield" by Ahmed and Khan (2022) used a field trial design. The population included groundnut farms in Punjab, Pakistan, with a sample of 75 fields selected through random sampling. Data validation involved soil health and yield assessments, with a reliability score of 0.86. Results showed that rhizobial inoculation significantly improved soil health and yield. Recommendations included the regular use of rhizobial inoculants to enhance groundnut production.

2.4   Theoretical Framework
The theoretical framework of this study integrates several foundational theories to elucidate the impact of plant bacteria on groundnut plants, including the Theory of Symbiotic Relationships, Nutrient Cycling Theory, and Soil Microbial Ecology Theory. These theories collectively provide a comprehensive understanding of how plant bacteria influence groundnut growth and soil health.

1   Theory of Symbiotic Relationships
The Theory of Symbiotic Relationships, particularly mutualism, underpins the interaction between groundnut plants and beneficial bacteria. This theory, as articulated by Darwin (1859) and further developed by modern biologists, posits that symbiotic interactions, where both partners benefit, are crucial for optimizing plant health and productivity. In the context of groundnut plants, beneficial bacteria, such as *Rhizobium* species, form symbiotic relationships with plant roots, enhancing nitrogen fixation, which is crucial for plant growth and development. This mutualistic relationship provides the plant with essential nutrients while offering the bacteria a stable environment and organic compounds from the plant (Freiberg et al., 1997). This theory is instrumental in understanding how plant bacteria contribute to groundnut yield and quality improvements.

2   Nutrient Cycling Theory
Nutrient Cycling Theory explains the processes through which nutrients are transformed and transferred through different environmental compartments, including soil, plants, and microorganisms. This theory, initially proposed by Hsu (1976), is crucial for understanding how plant bacteria influence nutrient availability and soil fertility. Beneficial bacteria, such as phosphate-solubilizing bacteria (e.g., *Bacillus* spp.), play a significant role in nutrient cycling by converting unavailable forms of nutrients into forms that plants can readily absorb. This process is essential for improving soil

fertility and supporting plant growth (Vassilev et al., 2006). The theory also highlights how these bacteria interact with other soil microorganisms, contributing to the overall nutrient dynamics within the soil-plant system.

3   Soil Microbial Ecology Theory

Soil Microbial Ecology Theory focuses on the diversity, function, and interactions of soil microorganisms and their impact on soil health and plant productivity. This theory, advanced by researchers such as Coleman et al. (2004), emphasizes the role of microbial communities in soil processes, including organic matter decomposition, nutrient cycling, and disease suppression. In the context of groundnut plants, beneficial bacteria contribute to soil health by enhancing microbial diversity and activity, which can lead to improved soil structure, nutrient availability, and disease resistance. The theory underscores the importance of microbial interactions in maintaining soil health and supporting sustainable agricultural practices (Singh et al., 2010).

4   Integration of Theories

Integrating these theories provides a holistic view of how plant bacteria influence groundnut growth and soil health. The Theory of Symbiotic Relationships explains the direct benefits of bacterial interactions with plant roots, while Nutrient Cycling Theory addresses the indirect benefits through nutrient availability and soil fertility. Soil Microbial Ecology Theory complements these insights by highlighting the broader impact of bacterial communities on soil health and ecosystem functions. Together, these theories offer a comprehensive framework for understanding the complex dynamics between plant bacteria and groundnut plants, guiding practical applications for enhancing crop productivity and sustainability.

2.5   Challenges and Limitations

The study of plant bacteria's effects on groundnut plants encounters several challenges and limitations that can impact research outcomes and practical applications. These challenges include issues related to experimental design and methodology, biological variability, environmental factors, scalability of results, and knowledge gaps.

1   Experimental Design and Methodology

One significant challenge in researching the effects of plant bacteria on groundnut plants is designing experiments that accurately reflect real-world conditions. Many studies rely on controlled environments or greenhouse settings, which may not fully capture the complexities of field conditions. For instance, controlled environments often fail to replicate the diversity of soil microbial communities and environmental variables present in natural settings (Glick, 2012). This limitation can affect the generalizability of the results. Additionally, methodological inconsistencies, such as variations in the application methods of bacterial inoculants and differences in measurement techniques, can lead to variability in findings and difficulty in comparing results across studies (Kloepper et al., 2004).

2   Biological Variability

Biological variability among different strains of bacteria and among different groundnut cultivars presents another challenge. The efficacy of plant bacteria can vary widely depending on the bacterial strain and its compatibility with specific groundnut varieties. For example, *Rhizobium* strains may have different levels of effectiveness in nitrogen fixation depending on the groundnut cultivar they are associated with (Peoples & Herridge, 1990). This variability makes it challenging to develop universal recommendations for bacterial inoculants. Moreover, the genetic diversity of bacterial populations can influence their performance in enhancing plant growth or suppressing diseases, complicating the establishment of standardized practices (Lugtenberg & Kamilova, 2009).

3   Environmental Factors

Environmental factors, including soil type, climate, and local agricultural practices, play a crucial role in the effectiveness of plant bacteria. Soil pH, moisture levels, and temperature can significantly affect bacterial activity and survival, as well as plant-bacteria interactions (Khan et al., 2009). For instance, beneficial bacteria may perform well in one soil type but be less effective in another due to differences in nutrient availability or soil structure. Environmental variability can therefore limit the applicability of research findings to different regions and conditions. Additionally, climate change and its associated impacts on soil and plant systems add another layer of complexity to understanding the interactions between plant bacteria and groundnut plants (Smith et al., 2018).

4   Scalability of Results

Translating research results from small-scale or experimental settings to larger agricultural operations can be challenging. Studies that demonstrate positive effects of plant bacteria on groundnut growth and health in controlled environments may not always yield the same results in large-scale field trials. Factors such as application methods, cost, and practical implementation play a crucial role in scaling up research findings (Singh et al., 2010). Moreover, the adoption of beneficial bacteria in large-scale farming may be hindered by economic considerations and the need for additional infrastructure or training for farmers (Thomas et al., 2021).

5   Knowledge Gaps

There are also significant knowledge gaps regarding the long-term effects of plant bacteria on soil health and plant productivity. While short-term studies often show promising results, the long-term impacts on soil microbial

communities, soil health, and sustainability are less well understood. Long-term studies are necessary to evaluate how continuous application of plant bacteria affects soil ecosystems and crop yields over time (Giller, 2001). Additionally, the interaction of plant bacteria with other soil amendments and pest management practices requires further investigation to develop comprehensive management strategies (Reddy & Rao, 2023).

In summary, addressing these challenges requires a multi-faceted approach, including improved experimental designs, consideration of biological and environmental variability, and long-term studies to fill knowledge gaps. By overcoming these limitations, research on plant bacteria's effects on groundnut plants can provide more reliable and actionable insights for improving agricultural practices and sustainability.

2.6 Future Directions and Research Needs

As research into the effects of plant bacteria on groundnut plants continues to evolve, several key areas of future exploration and research needs emerge. Addressing these areas will enhance our understanding of plant-bacteria interactions and their practical applications in agriculture.

1. Exploration of Bacterial Diversity and Functionality

Future research should focus on the exploration of the diversity and functionality of plant-associated bacterial communities, particularly those that interact with groundnut plants. The diversity of bacterial strains and their specific roles in promoting plant health and growth are crucial areas that need further investigation. For instance, studies could delve into the genetic and functional diversity of beneficial bacteria in different soil types and environmental conditions. Understanding how different bacterial strains contribute to nitrogen fixation, phosphate solubilization, and other beneficial processes will help in selecting and applying the most effective bacterial inoculants (Glick, 2012; Lugtenberg & Kamilova, 2009).

2. Long-Term Impact Studies

There is a need for long-term studies to assess the sustainability and impact of plant bacteria on soil health and crop productivity over extended periods. While short-term studies often show immediate benefits, long-term research is necessary to evaluate how continuous application of plant bacteria affects soil ecosystems, microbial communities, and overall soil health. This will help in understanding the persistence of beneficial effects and potential risks associated with prolonged use (Giller, 2001; Singh et al., 2010).

3. Interaction with Soil Amendments and Fertilizers

Future research should explore how plant bacteria interact with other soil amendments and fertilizers. Understanding these interactions can help in developing integrated soil management practices that maximize the benefits of bacterial inoculants while minimizing the reliance on chemical fertilizers. Studies could investigate how plant bacteria affect the efficacy of various soil amendments and how they influence nutrient dynamics in the soil-plant system (Reddy & Rao, 2023; Vassilev et al., 2006).

4. Impact of Climate Change

The impact of climate change on plant-bacteria interactions and their effectiveness in promoting crop health is a critical area for future research. Climate change factors such as temperature fluctuations, altered precipitation patterns, and increased CO_2 levels can affect bacterial activity and plant responses. Research should focus on understanding how these changes influence the effectiveness of plant bacteria in different climatic scenarios and developing strategies to mitigate potential negative effects (Smith et al., 2018).

5. Development of Novel Inoculants

Innovative approaches to developing novel bacterial inoculants tailored for groundnut plants are needed. Advances in biotechnology and genetic engineering could lead to the creation of custom-designed bacterial strains with enhanced capabilities for promoting plant growth, nutrient uptake, and disease resistance. Research should focus on exploring new bacterial strains, engineering bacterial genomes, and evaluating their performance in diverse agricultural settings (Thomas et al., 2021; Zhang & Liu, 2020).

6. Socioeconomic and Practical Aspects

Future research should also address the socioeconomic and practical aspects of adopting plant bacteria in agriculture. This includes studying the cost-effectiveness of bacterial inoculants, their impact on farmer livelihoods, and the barriers to their widespread adoption. Understanding these aspects will help in developing policies and strategies to facilitate the integration of plant bacteria into mainstream agricultural practices (Chandra et al., 2023; Liu et al., 2017).

7. Field-Scale Implementation

Finally, research should focus on translating laboratory and greenhouse findings to field-scale implementations. Large-scale field trials and on-farm demonstrations are essential to evaluate the real-world effectiveness of plant bacteria in diverse agricultural systems. These studies should consider varying soil types, climatic conditions, and farming practices to provide comprehensive recommendations for practical application (Jain & Singh, 2019; Patel & Sharma, 2022). Addressing these future directions and research needs will advance our understanding of plant bacteria's roles in

agriculture, improve their practical applications, and contribute to sustainable farming practices. Collaborative efforts across disciplines and sectors will be crucial in driving innovation and achieving significant advancements in this field.

Conclusion

The review of the effects of plant bacteria on groundnut plants highlights several critical findings. Plant bacteria, particularly beneficial strains, play a pivotal role in enhancing groundnut growth, improving seed germination, and promoting robust root development. These bacteria contribute to plant health through mechanisms such as nitrogen fixation, phosphate solubilization, and the production of plant growth-promoting hormones. The interaction between groundnut plants and these bacteria not only boosts plant growth but also positively impacts soil health by improving soil structure and fertility. Furthermore, beneficial bacteria have shown potential in disease management, offering biocontrol options against various bacterial pathogens that affect groundnuts.

1   Implications for Groundnut Cultivation

The positive effects of plant bacteria on groundnut cultivation have significant implications for agricultural practices. The incorporation of beneficial bacteria into groundnut farming can lead to enhanced crop yields and improved soil health, which are crucial for sustainable agricultural practices. By adopting bacterial inoculants, farmers can reduce their dependence on chemical fertilizers and pesticides, thereby promoting more environmentally friendly farming practices. The integration of plant bacteria can also contribute to increased soil fertility and resilience, which are essential for coping with the challenges posed by climate change and soil degradation. The practical applications of these findings can guide the development of innovative strategies for groundnut cultivation, fostering more efficient and sustainable agricultural systems.

2   Final Thoughts on the Role of Plant Bacteria

In conclusion, plant bacteria play a crucial role in supporting groundnut plants and enhancing agricultural sustainability. Their multifaceted contributions—from promoting plant growth and nutrient uptake to improving soil health and managing plant diseases—underscore their importance in modern agriculture. The research underscores the need for continued exploration of plant bacteria's potential to address agricultural challenges and optimize crop production. Future research should focus on expanding our understanding of bacterial diversity, long-term impacts, and practical applications to fully harness the benefits of these microorganisms. Overall, the integration of beneficial plant bacteria represents a promising avenue for advancing agricultural practices and achieving more sustainable and productive farming systems.

Summary

This study has provided a comprehensive review of the effects of plant bacteria on groundnut plants, revealing several critical insights into their role in agriculture. The research highlights the beneficial impact of plant bacteria on various aspects of groundnut cultivation, including seed germination, root development, plant growth, and overall biomass production. Key findings indicate that plant bacteria contribute significantly to enhancing groundnut health through processes such as nitrogen fixation, phosphate solubilization, and the production of growth-promoting hormones. These interactions not only support plant development but also improve soil health by fostering better soil structure, nutrient availability, and microbial diversity.

The review also emphasizes the potential of plant bacteria in managing groundnut diseases. Beneficial bacteria can act as biocontrol agents, suppressing pathogenic bacteria and reducing the incidence of diseases. This dual role of promoting plant growth and managing soil health and plant diseases highlights the versatility and importance of plant bacteria in sustainable agriculture.

Furthermore, the integration of plant bacteria into groundnut farming practices offers several advantages, including reduced reliance on chemical fertilizers and pesticides, improved soil fertility, and enhanced resilience against environmental stresses. These benefits align with the broader goals of sustainable agriculture, emphasizing the need for practical applications and widespread adoption of beneficial bacterial inoculants in groundnut cultivation.

Recommendations

Based on the findings of this study, several recommendations can be made to optimize the use of plant bacteria in groundnut cultivation and to address areas where further research is needed:

1. **Promotion of Beneficial Bacteria**: Agricultural stakeholders should promote the use of beneficial plant bacteria as part of integrated pest and nutrient management systems. Farmers should be encouraged to use bacterial inoculants that have demonstrated efficacy in enhancing groundnut growth and disease resistance. Extension services and agricultural training programs should include information on the benefits and application methods of these inoculants.

2. **Research and Development**: Continued research is needed to explore the diversity of beneficial bacterial strains and their specific roles in groundnut cultivation. This includes investigating how different bacterial

strains interact with various groundnut cultivars and environmental conditions. Research should also focus on developing novel bacterial inoculants with enhanced capabilities for promoting plant health and improving soil fertility.

3. **Field Trials and Practical Applications**: Large-scale field trials should be conducted to validate the findings from controlled studies and to assess the effectiveness of plant bacteria under diverse agricultural conditions. These trials will provide valuable insights into the practical applications of bacterial inoculants and help refine best practices for their use in groundnut farming.

4. **Addressing Knowledge Gaps**: Future research should address gaps in our understanding of the long-term impacts of plant bacteria on soil health and crop productivity. Studies should also explore the interactions between plant bacteria and other soil amendments or pest management practices to develop comprehensive agricultural strategies.

5. **Sustainable Practices**: Encourage the adoption of sustainable agricultural practices that incorporate beneficial plant bacteria. This includes promoting practices that reduce the environmental impact of agriculture, such as reduced chemical inputs and improved soil management. Farmers should be supported in transitioning to these practices through subsidies, technical support, and access to effective bacterial inoculants.

6. **Climate Change Adaptation**: Investigate the impact of climate change on plant-bacteria interactions and their effectiveness. Research should focus on understanding how changing climate conditions affect bacterial activity and plant responses, and developing strategies to adapt bacterial applications to changing environmental conditions.

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Nematode as a Potential Threat to Food Security in North East Nigeria and the Way Forward.

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Abstract

The contribution of agriculture to the growth and development of a nation cannot be undervalued. However, the production of food crops in Nigeria is seriously threatened by ongoing conflicts between farmers and herders, banditry, kidnapping, Boko haram insurgency, inflation, climate change, and biotic factors, particularly in the northeastern part of the country. Plant Parasitic Nematode (PPN), a soil microorganism is considered to be one of the most devastating factors threating agricultural production in the region. The impact of damage caused by PPN is estimated to be about at 8.8 – 14 % annually, which is responsible for crop losses estimated to be in excess of 173 billion USD worldwide. This figure will most likely increase if appropriate management and control measures are not taken. Therefore, it is expedient that farmers within the northeastern region of Nigeria take precautionary management measures before, during and sometime after each farming season in order to curtail the problem of damage cause by PPN.

 Key words: Nematode, *Meloidogyne*, Northeast , Threat, Plant Parasitic Nematode (PPN)

1 Introduction

Adamawa, Bauchi, Borno, Gombe, Taraba, and Yobe are the six states that make up the North East, one of Nigeria's largest geopolitical zones. It occupies over one-third of the country's total territory and is both a political and geographic region (Akinyemi *et al.*, 2022). These states are recognized for their agricultural and livestock rearing practices, which have a significant positive economic impact on both the local economy and the nation as a whole (Food and Agriculture Organization FAO, 2021). However, boko haram insurgency, banditry, kidnapping, farmers' herders conflict, inflation, impact of climate and biotic factors continue to threating agricultural production in the region leading to an increase hunger crisis in Nigeria at large, with 26.5 million people across the country projected to serious hunger (FAO, 2021). Sub-Saharan Africa (SSA) is experiencing an increase in food insecurity, hunger, and malnutrition these are the three of the world's most pressing issues according to Alao *et al.* (2020). The world's progress toward reaching Sustainable Development Goal-2 zero hunger by 2030 has slowed down due to a number of main issues, including economic recessions, conflicts resulting from climatic variability, and biotic variables (Agbiboa, 2015). The fundamental factors of growing inequality and poverty increase the frequency and intensity of these drivers (FAO, 2021).

About 4.4 million people in Borno, Adamawa, and Yobe states are food insecure due to conflict that has caused 2.2 million people to be relocated in the Northeast (Alao *et al.*, 2020). According to D'Amato (2018), three million of them reside in Borno State, the insurgency's epicenter. Nigeria experiences frequent floods and droughts, which have a negative effect on agricultural productivity and make people more vulnerable, particularly in rural regions (Devereaux and Edwards, 2019).More so, soil microorganism such as Plant Parasitic Nematode (PPN) has a profound impact on the agricultural food production which has led to massive crop loss, estimated at 8.8- 14% annual crop loss at an estimated cost of approximately 173 billion (Ahuja and somyanshi, 2021).

2 Economic effect of Plant Parasitic Nematode

Plant parasitic nematodes, particularly the root knot nematodes (*Meloidogyne*), are widely recognized as a major obstacle to increasing crop production, especially in developing countries like Nigeria (Aghale, 2017). One of the major issue with root knot nematodes infestation on agricultural crops in tropical and sub-tropical region of the world   is how quickly the problem escalates (Aghale, 2017). However, accurate statistics on crop losses caused by *Meloidogyne* spp are hard to come by. Estimated crop losses due to nematodes in various crops, such as cowpea, cotton, okra, tomato, tobacco, banana, maize, etc., vary from 20-100% in different parts of the world (Fawole, 2018). The extent of crop losses ranges from minor, less than 1%, to complete destruction, and the level of damage depends on the population density of nematodes, crop susceptibility, and environmental conditions such as fertility, moisture, and the presence of other pathogenic organisms that may interact with nematodes (Fawole, 2018). Furthermore, it was revealed that the 20 life-

sustaining crops that are the main sources of human nutrition had an estimated yearly production loss of 10.7%, and the projected annual yield loss of the world's key crops owing to damage by plant parasitic nematodes was 12.3%.it Additionally, it was reported that the expected annual production loss of plant parasitic damage to the world's major crops Cassava (8.4%), citrus (14.2%), cocoa (10.5%), maize (10.2%), cotton (10.7%), groundnut 12%, potato (12.2%), rice (10.0%), sorghum (6.9%), soy beans (10.6%), sugar cane (15.3%), wheat (7.0%), tobacco (14.7%), and sweet potato (10.2%) are the crops that have yield losses (FAO, 2016). For the majority of crops in Nigeria and other nations, reliable statistics on yield losses are not easily accessible (Adesiyan *et al.*, 2017). Plant parasitic nematodes have been found to reduce yields in studies on tomato, maize, and cowpea by 28–64%, underscoring their impact on food security (Adesiyan, *et al.*, 2017). According to Aghale (2017), the root knot nematode damages a variety of agricultural crops, causing delayed maturation, decreased yield and crop quality, higher production costs, and income loss. Nematode attacks can lead to significant losses of 20 – 30% in crops like maize, cowpea, sorghum, sugar cane, citrus, and vegetables Aghale (2017). More so, disfiguration in root and tuber crops not only decreases market value but also leads to consumer rejection (Aghale, 2017). For example, galled yam tubers experience a 39-52% reduction in price and lose more weight during storage compared to healthy tubers (Nwauzor and Fawole 2015). Nematode damage significantly affects yam quality, yield, and overall losses both in the field and during storage (Nwauzor and Fawole 2015). In Nigeria's irrigated areas, a 40% crop loss has been reported, with tomato experiencing losses ranging from 10 – 89% (Nwauzor *et al.*, 2019). Nematode infections cause more severe crop losses in warmer climates and areas with less access to food and fiber. Plants impacted by nematodes show signs of nutrient stress and dryness, which frequently results in incorrect diagnoses (Aghale, 2017). Nematode damage reduces root effectiveness in Musa spp. (bananas and plantains) and can cause root necrosis and death in crops, which can collapse plants and result in the complete loss of immature fruit (Gowen *et al.* 2015). Across the world, areas where maize is grown have reported harmful populations of a number of root knot nematode species, including *M. incognita* and *M. javanica* in India (McDonald and Nicol 2017). And in Pakistan, as well as in the USA, according to multiple writers (McDonald and Nicol 2017). Leaf chlorosis, uneven growth, and stunting are signs that are visible above ground. Large or little, terminal or sub-terminal, or completely missing, are possible characteristics of root galls. Because of this, maize has frequently been incorrectly believed to be a poor or non-host for nematodes known to cause knots in roots (McDonald and Nicol 2017).). *Pratylenchus* brachyurus has been linked to a 28.5% yield drop in Nigeria, according to reports, and this reduction is coupled with a 50% rise in nematode density (Egunjobi 2019). According to Adesiyan *et al.* (2017), it has been challenging to estimate the precise amount of economic losses brought on by root-knot nematodes, particularly in underdeveloped nations where crops are rarely farmed as sole crops. Adesiyan *et al.* (2017). Furthermore, many populations of plant-parasitic nematodes can be found in the soil, often feeding on the same plants as other diseases such fungi, bacteria, and viruses (Adesiyan *et al.* (2017).

3 Management /Control Measures

Numerous methods have been considered for managing and or controlling plant parasitic nematodes, with the preferred immediate solution being the use of nematicides, despite the environmental concerns and pesticide residues (Aghale, 2017). The use of resistant plant types, integrated pest management, cultural and land management techniques, and the more recent usage of ethno medicinal plants (botanicals) are some other means of control. Nigerian farmers have found success with cultural control techniques such crop rotation, bush fallow, mulching, dry season plowing, trap crops, and flooding of farm lands (Aghale, 2017). Crop rotation, which involves switching sensitive crops with non-host crops, poor hosts, or crops resistant to or tolerant of root-knot nematodes, is the most successful cultural technique for controlling nematode pests among these (Aghale, 2017). The crops employed in rotation sequences were identified by Atu & Okuji (2019) as *Amaranthus* spp., *Citrullus laratus*, *Zea mays*, *Manihot* spp., and the extremely resistant *Mucuna prurians*. Farmers haven't, however, implemented any cropping plans that include plants that inhibit nematodes known to cause knotting in roots (Aghale, 2017).

The introduction of nematodes through contaminated plant materials on uninfected soil has created a vicious circle, resulting in infestations of new plants and soil. The introduction of resistant plant cultivars is another low-cost cultural strategy for nematode control (Aghale, 2017). Many crops have notable yield gains as a result of cultivars that have been engineered to be resistant to nematode pests or that are naturally resistant to them. It is clear, though, that these cultivars are resistant to a relatively small range of worm taxa. There are not many known resistant yam variants, and those that exist are primarily cultivars and species with little consumer demand (Onyenobi, 2017). Another cultural control strategy used by smallholder farmers is intercropping (Onyenobi, 2017). Most traditional intercrops such as *Hibiscus esculentum*, *Corchoruso litorus*, and *Cucurbit*a pepo are highly susceptible to root knot nematodes, and mixed cropping with other host crops of *Meloidogyne spp* alongside yam plants is likely to increase nematode populations and damage severity (Atu, 2019). Most effective means of control in crop production (Onyenobi, 2017). Onyenobi (2017) successfully pre-treated seed yams with oxamyl to control bio deterioration prior to Growing different crops on the same piece of land in a random fashion results in minimal damage to a very susceptible the crop (Atu, 2019). Peasant farmers in Nigeria therefore experience less nematode issues than those in areas where modern agriculture is practiced as sole cropping.

Chemical control, which involves the use synthetic nematicides to control nematodes, is an efficient way to manage nematodes. Nonetheless, these compounds' established environmental risks have resulted in their deregistration (Aghale, 2017). Given the speed at which target species gain resistance to chemical nematicides and the accompanying issues of high cost and application expertise, there is a growing body of questioning surrounding these chemicals (Aghale, 2017). The usage of nematicides has been linked to an increase in sterility and birth malformations in South East Asia, as reported by Yaradua (2017), raising concerns about potential health risks. The humus layer in particular is where these pesticides are frequently absorbed into the soil, where they may have an indirect or direct effect on the microbiota of the soil, changing the rate at which organic matter breaks down and the flow of nutrients. Earthworms and other soil organisms are very hazardous when exposed to chemical nematicides, as Yaradua (2017) has observed. Fifty thousand hectares of Costa Rican banana plantations were irreversibly destroyed by chemical control of *Radophilus* nematodes. Plant parasitic nematodes have been thought to be controlled by botanical methods. This strategy is motivated by the fact that traditional nematodes are unavailable to farmers with limited resources, and plants such as neem are effective at controlling nematodes; these results are consistent with farmers' preference for Integrated Pest Management Techniques. The neem tree, *Azadirachta indica*, has been utilized more frequently as a cheap source of nematicide; its nematicidal qualities have been examined (Jacobson, 2017)

Plant extracts are preferred over chemical nematicides due to the additional benefit of environmental safety; other plants, like Crotolaria and Piper nigrum, are presently under evaluation. Farmers, especially those with limited resources, have found success using botanicals to protect crops from pests and diseases while they are in storage or in the field. According to Salako (2015), botanical pesticides are reasonably priced and comprise a complex mixture of active components that operate on different stages of the nematode lifecycle, thus making it difficult for nematodes to build resistance. Yaradua (2017) asserts that botanical insecticides are safe for the environment, simple to make, and renewable locally. According to Egunjobi (2014), a number of plants have been identified as having nematostatic or nematicidal qualities in their leaves, barks, seeds, fruits, and seeds. Root extracts from *Chromole anaodorata*, *Ricinus communis*, *Lycopersicum esculentum*, and *Vigna unguiculata* were successfully employed by Amosu (2018) against *Meloidogyne spp* in vitro. Salawu (2016) discovered that *Heterodera sachari* eggs could not hatch when *Azadirachta indica*, *Chromolaena odorata*, and *Amnona muricata* were used against them. According to Triantaphyllou (2017) and Eisenback (2017), *A. indica* and *P. nigrum* are both beneficial substitutes for synthetic pesticides in the production and storage of yams, and they are both employed locally in ethnomedicine practices without leaving any toxicological residues.

4 Conclusion

One cannot underestimate the contribution of agriculture to national economic growth and development. The abundance of plant parasitic nematodes in the soil of northeastern Nigeria poses a threat to food crop production and food security, about 89 metric tons of root knot nematode infestations occurred in 2008 in Nigeria, affecting root and tuber crops, which make up the majority of the country's agricultural output. It is essential to educate farmers about the problems caused by plant parasitic nematodes and how to handle them. Nematodes can impede productivity and the benefits that come with it if they are not properly control, particularly in this period of rapidly increasing population. Farmers must be able to identify nematode problems in their regions in order to understand the significance of control efforts. But because of widespread illiteracy and a dearth of technical knowledge in nematode research, accomplishing this goal has been challenging. Due to their high costs and small profit margins, resource-poor farmers are forced to rely more on traditional techniques of pest management. These less expensive techniques that don't require specific knowledge of nematode control should be prioritized in the future

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FLOOD LEVEL MAPPING FROM DIGITAL ELEVATION MODEL (DEM) THROUGH REMOTE SENSING/GIS IN YOLA CATCHMENT AREA, NORTHERN UPPER BENUE TROUGH, NIGERIA

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Abstract

Yola catchment has recently experienced extreme climatic conditions attributed to climate change, leading to a substantial increase in rainfall intensity and, consequently, more frequent flooding in the region. Effective management of such disasters can be achieved through the utilization of precise datasets, such as Digital Elevation Models (DEMs), to delineate flood levels. DEMs are preferred due to their accessibility and lower computational demands in modeling applications. The topographic data derived from DEMs serve as crucial input parameters for comprehensive flood level mapping. Methods based on DEMs facilitate the identification of areas that are geomorphologically susceptible to flooding. In this study, DEM-based techniques were utilized to delineate areas that are susceptible to flooding due to their geomorphological characteristics. DEM data from SRTM satellite imagery were processed using Arcgis10.6 to categorize flood level areas according to the terrain and landform characteristics of the study area. The DEM classified flood levels into two categories were imported into ArcGIS 10.6 and reclassified. The analysis revealed two classifications of flood levels: the most floodable areas, which constitute 33.3% of the study area and cover 170.6 km², impacting nine villages, and the less floodable areas, which account for 25.41% of the study area, covering 130.1 km² and affecting twenty villages. This flood level mapping is intended to enhance awareness among residents, prioritize land development, and improve emergency preparedness, including aid and relief operations in areas at high risk of flooding in the future.

Key words: Flood level, DEM, Flooding, GIS

1. Introduction

Floods are one of the most common widespread, instantaneous, severe, frequent, and devastating natural hazards. They pose threats to human lives and the environment and cause severe economic damage in different regions of the world (Sun et al 2020; Daniel, 2016; Khan et al, 2011; Karki, et al, 2011; Bajabaa et al. 2014; Elnazer et al. 2017; McCarthy, 2001). In addition to being a natural geophysical hazard, it is a potentially harmful physical phenomenon that may result in loss of life, injury, disease, collateral damage, economic hardship, and environmental degradation (Du et al. 2013; Youssef et al. 2011; UNISDR, 2004). Floods have been the most common type of geophysical disasters, and is largely a localized event caused by extremely heavy torrential rainfall that may last for few minutes/hours or days, weeks, or longer resulting in the overflow of the natural river banks (Brammer, 1990; Kamal et al. 2018), Other hazards associated with floods include landslides, mud flows, violent convection storms, water contamination, prolonging surface runoff, and ecological impacts (Collier 2007). As a result of global climate change, flood intensity and frequency are expected to increase tremendously in the future (Jonkman & Dawson 2012; Adnan & Kreibich, 2016; Field et al, 2012; Rahman et al. 2019). Flood forecasting is always difficult to predict due to lack of real time data. The incidence of flood events has been attributed to climate change, rapid urbanization, rise in sea level, high population density, land degradation by pollutants, modified and intensified land use (Clark, 1998).

Therefore, flood is a natural phenomenon that persistently overflows large volume of water that occur due to (extreme hydrological runoff event) prolonged heavy rainfall, rapid accumulation and release of runoffs and overflow of this water flashing beyond its normal confines (Leopold et al, 2012). According to WHO (2003), flooding affects 140 million

people annually on average and can have devastating and severe effects on many countries around the world. Examples include the 1959 floods in China and the 1974, 1987, 1988, and 1998 floods in Bangladesh, the annual flooding in southern Bandung, Indonesia, and the December 2004 tsunami in Southeast Asia, as well as settlements around the Mississippi River in the United States. (Ahem *et al.* 2005). Africa has had devastating floods in recent years in places including Burundi, Djibouti, Kenya, Rwanda, Morocco, Somalia, and Uganda. According to statistical data, floods cause 34% of all natural disasters worldwide in terms of number and 40% of losses (Lyu et al., 2019; Petit-Boix et al., 2017; Yalcin & Akyurek, 2004). Flooding poses a threat to more than one-third of the world's geographical area and can impact up to 82% of the global population. Over 90 nations and 196 million people are at risk of catastrophic flooding (Karki et al., 2011).

Nigeria is therefore not an exception to nations that have recently suffered from the destructive consequences of flooding. Approximately 431 people died and an estimated 1.3 million people were displaced in 2012. in addition, 1525km^2 of farmland were submerged from thirteen states MISNA, 2012). States in Nigeria such as Adamawa, Taraba, Benue, Kaduna, Kano, Sokoto, Bayelsa, Bauchi, Nasarawa, Niger, Kogi, Edo, and Anambra States are the most vulnerable states due to flooding have also experienced the devastating effects of flood annually (FGN, EU UN 2012). According to the Adamawa State Emergency Management Agency (SEMA), different levels of damage have been reported in several sites within the northeastern Nigerian state of Adamawa as well as other parts of the nation since the start of the rainy season (Table 1). Significant damage has been done to shelters, farmlands, and infrastructure due to heavy rains and severe winds (IOM, 2022). The previous few decades have seen floods in a number of riverine villages. Since August 2022, the state's central region has been mostly affected by high rains and flooding, which worsened in October 2022 and cost 173,049 people in 11 local council areas their property, crops, and cattle. Along the river banks, more than 19,000 people were temporarily relocated from 149 settlements spread over seven local council regions. Fifteen individuals were killed and 19 more were reported missing. When water from Cameroon's Lagdo Dam was released in October 2022, the upstream flow of water from the country's highlands caused the Benue River to burst its banks and flood nearby settlements. Flood disasters' spatial distribution in central Nigeria was mapped by Ojigi et al. (2013). Identifying all sites that are susceptible to flooding is one method to lessen its effects. Flooding is mostly caused by river flooding and heavy rains. The Benue and Niger, Nigeria's two main rivers, spilled their banks, submerging nearby farms and communities. The main causes of floods are heavy rainfall and river flooding. Intense flooding resulted from the two main rivers in Nigeria, the Benue and Niger, overflowing their banks flooding farmlands and communities along the flood plains. Areas (depth and extent) that may be at danger of flooding under conditions of excessive rainfall are identified by flood level mapping, which is a crucial component of suitable land use planning and effective management of future flooding occurrences in flood-prone areas. Administrators and planners can more quickly identify danger regions and prioritize their mitigation efforts because to the charts and maps it produces, which are quick and easy to read (Meyer et al. 2001). In-depth knowledge of flooding in these areas has not been established, and inadequate spatial coverage of hydrological databases makes it difficult to accurately forecast floods and manage flood risk. Despite the significant and devastating impact that floods have on the livelihoods of those who live in these areas, no effort has been made to identify areas most at risk of flooding or to delineate the boundaries of flood level at the community level. Thus, this study looks at and maps the flood level in Adamawa state's Yola catchment, which is situated in the River Benue's flood plains. According to Jonkman and Kelman (2005), Khan et al. (2011), and Dihn, Balica, Popescu, and Jonoski (2014), flood vulnerability is expected to increase in frequency and severity due to rapid urbanisation, climate change, and extreme weather conditions like heavy rains and river discharge conditions that endanger human life in various parts of the world. The current trend and future scenarios of flood risks necessitate the requirement for accurate geographical and temporal information and databases on potential hazards and flood risks. Emergency services and early warning systems must assess flood vulnerability in order to create management plans for the prevention and mitigation of future flood occurrences (Tehrany et al. 2015).

Numerous comprehensive tools, such as HAZUS, a GIS-based natural hazard analysis tool intended for assessing flood hazard, and HECFDA, a computer software that assists crop engineers with vulnerability analysis of flood risk reduction measures, are used by numerous research groups worldwide. According to Khan et al. (2008), Saha et al. (2005), Wang et al. (2013), and Pourghasemi et al. (2014), RS and GIS techniques offer a suitable platform for manipulating and evaluating the relevant information in order to create suitable hazard zones with ease. RS and GIS techniques are very helpful when evaluating flood damage caused by large rainfall in a catchment area or sea wave surges in coastal areas (Pradhan et al. 2014; Patel & Srivastava, 2013). Many research organisations around the world use a number of comprehensive tools, such as HECFDA, a computer program that helps crop engineers with vulnerability analysis of flood risk reduction policies, and HAZUS, a GIS-based natural hazard analysis tool designed for evaluating flood hazard. In order to easily demarcate appropriate hazard zones, RS and GIS approaches provide an appropriate platform for manipulating and analysing all pertinent information (Khan et al. 2008; Saha et al. 2005; Wang et al. 2013; Pourghasemi et al. 2014). When assessing flood damage produced by heavy rainfall in a catchment area or sea wave surges in coastal locations, RS and GIS approaches are extensively useful (Pradhan et al. 2014; Patel & Srivastava, 2013). Geographic information systems (GIS) have recently made a wide range of tools available for the quicker and less expensive creation

of flood level maps, flood monitoring in flood-affected areas, and forecasting of areas that are expected to flood as a result of high river water levels. In order to determine flood levels, data from digital elevation models (DEM) was compiled using a geographic information system. In order to map the flood levels in a hydro basin, the Yola Catchment and the Northern Upper Benue trough watershed, DEM serves as a fundamental digital data collection. Digital elevation models have recently been used extensively in hydrological applications to help manage flood risk and flood level by storing and managing hydrological data and generating maps of flood inundation and hazards. These models are also used to determine the runoff response to rainfall (Garbrecht and Martz, 1996). In relation to any reference datum, the land surface elevation is represented digitally via a Digital Elevation Model (DEM). When referring to any digital representation of a topographic surface, the term DEM is commonly used. (Balasubramanian, 2017) DEM is the most basic type of digital topography represented. With DEM, a number of features pertaining to the surface hydrology of a certain location can be identified.

2. Study area

The research region is located in the upper Benue trough's Yola catchment, which runs east-west of the Yola Basin (Yola Arm). With a land area of roughly 511.966 km^2, it is a section of the failed arm of a Cretaceous triple junction (Burke & Deway, 1973), which is located between latitudes 9° 5′ N – 9° 20′ N and longitudes 12° 25′ E – 12° 40′ E (Figure 1). The relief is primarily low-lying, ranging from below 110 m to 560 m on average. The River Benue cuts through the center of the research region and drains the hydrologic basin. The area is characterized by erosional and flood plains with several stream channels, and it is situated in the upper Benue trough catchment of the Yola arm. Seasonal flooding causes these erosional plains and floods, which are naturally rich in organic nutrients that are deposited there as flood water recedes. Seasonally, large amounts of sediment are deposited, particularly during floods, and are carried into the floodplains to aid in restoring the fertility of the soil. The research region is located in Nigeria's Sudan savannah, a semi-arid climate zone in Sub-Saharan Africa. It has two distinct seasons: a cold, rainy season which is from April to October and a hot, dry season starting November to April (Sebastian & Adetola, 2022).
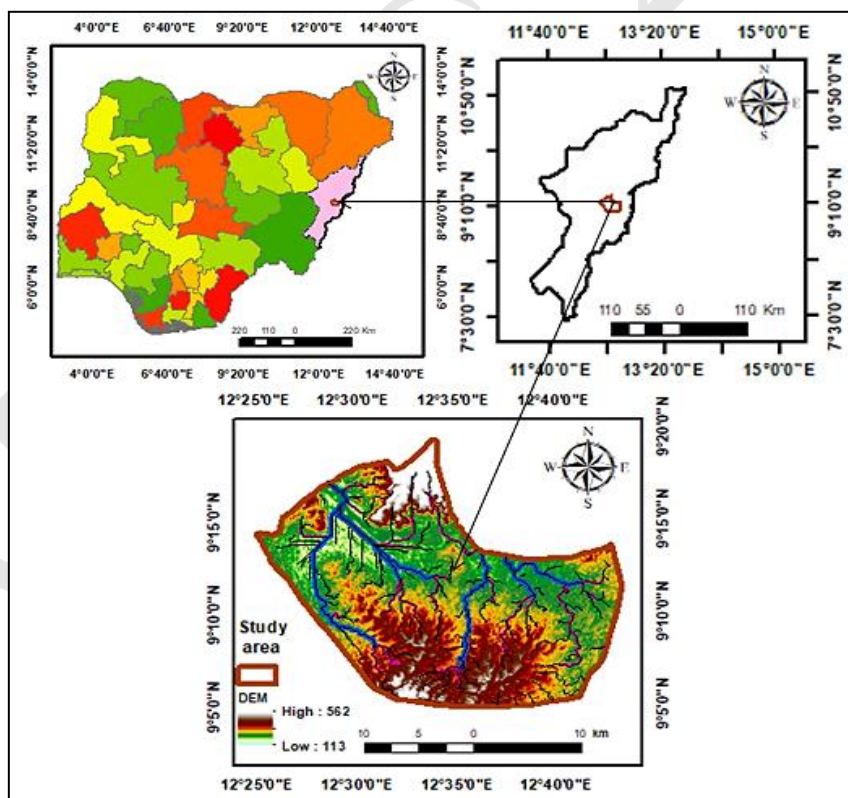

Fig. 1. Location Map of Yola Catchment area

Fig. 2 (a) Figure 2 Shows Google Earth satellite imagery showing an investigated stretch of River Benue located along Jimeta in the Yola catchment area. **(b)** River Benue **(c and d)** How heavy rain caused havoc in Yola, Adamawa capital Published on May 17, 2019, Published on May 17, 2019 Jim Ochetenwu

Table 1 *Source*: Estimation by the Assessment Team on the basis of official information. 2012

State	Damage	Losses	Total
Adamawa	68,423.6	1,562.0	69,985.7
Anambra	77,344.2	2,825.5	80,169.7
Bayelsa	396,074.0	6,393.8	402,467.9
Delta	34,509.5	12,856.9	47,366.4
Edo	6,841.7	3,615.8	10,457.6
Jigawa	5,443.3	5,813.3	11,256.7
Kebbi	47,103.2	1,649.3	48,752.6
Kogi	62,049.6	1,362.6	63,412.3
Nasarawa	25,744.9	1,450.4	27,195.4
Rivers	396,074.0	947.0	397,021.1
Taraba	36,351.1	10,392.7	46,743.8
Total	1,155,959.9	48,869.9	1,204,829.7

3.0 Materials and method

3.1 Processed SRTM Data Version 4.1

In order to accomplish the study's goals, we analyzed the DEM using a combination of remote sensing and GIS methods. The information was taken from the NASA/USGS SRTM data. Reuter et al.'s interpolation algorithms have been used to fill in the gaps in the original SRTM data. 2007 To create a drainage pattern and digitize the study watershed, the Shuttle Radar Topography Mission's digital elevation model was utilized. To create stream networks and define the watershed, a number of methods were employed. The morphological features of the basin were examined using the Arc GIS 10.6 program.

3.2 Digital Elevation Model (DEM)

A satellite data collection called the Digital Elevation Model (DEM) provides three-dimensional (3D) elevation information of the earth's surface. Digital surface models (DEM) are separated into two categories: digital surface model (DSM) and or the digital terrain model (DTM).

DSM is the elevation which is considered the height of all things including plants, buildings and so on, while DTM will consider only the bare ground at a certain area. General information of the earth's surface can be obtained or information of a specific area on the points that has been set on the e earth's surface (Jarvis, et al. 2008). These points depend on the distance from each other and are based on longitudes-latitudes or the UTM zone, or Universal Transverse Mercator coordinate system SRTM: In 2003, the Shuttle Radar Topography Mission (SRTM) products were first made available with horizontal resolutions of 30 and 90 meters. The interpolation algorithm has been used to process the published

datasets in order to fill the SRTM data hole (Reuter et al. 2007). According to Rodrigue et al. (2006), the SRTM absolute elevation errors at the 90% quantile (LE90) varied from 5.6 cm to 9.0 m. In this study, both 30 m and 90 m resolution DEMs were used, with error correction applied to the 90 m data.

3.3 Geo-referencing and Projection

ArcGIS 10.6 software was employed to georeference the satellite images utilized in this study, utilizing the geographic coordinate system (GCS_WGS_1984). Geographic coordinate systems represent locations using latitude and longitude derived from a spherical or spheroidal model, while projected coordinate systems employ X and Y coordinates based on a planar surface. The choice of projection influences the alignment and distortion experienced when representing the three-dimensional Earth on a two-dimensional map. For the purposes of this study, the suitable projected coordinate system for the Yola catchment area is WGS_1984_UTM_Zone_32 N (ESRI 1999).

3.4 Derivatives of DEM

The basis for creating several derivatives that offer information on the topography of the terrain is Digital Elevation Models (DEMs). Numerous scenarios, such as drainage analysis, watershed evaluation, and the measurement of volume changes between two surfaces, can benefit from the use of these models. They also play a key role in creating contour maps, performing visibility assessments, and locating surface depressions. Using ArcGIS 10.6 software, the derivatives from DEMs used in this study include slope maps, drainage patterns, watersheds, and contour representations of the study area.

3.5 Elevation and slope

Since water moves from higher altitudes to lower elevations, slope affects both the drainage pattern's flow direction and the quantity of surface runoff and infiltration (Figure 3c). Low-lying, level lands may flood more quickly than higher-lying, steeper-sloped places. In the northern and southern portions of the examined area, where the slope is steeper, high elevation is visible on the flank borders. Naturally, because they are prone places, low elevation and low slope have been given the greatest grade.**(Figures. 2a & c).**

3.6 Land use and land cover

Land use and land cover has an impact on the rate of infiltration, which is the interaction between the surface, groundwater as well as debris flow. Therefore, urban and grassland environments enhance the overland flow of water, whereas forests and lush vegetation stimulate infiltration. There is little waterlogged vegetation and agricultural land, and a significant amount of the investigated region is by bushes and sporadic trees. Flooding will be influenced by the study area's land cover and land use characteristics **(Figure 2e).**

3.7 Rainfall

The study area's rainfall distribution was created using the CRU TS version 4.07 dataset for annual rainfall between 2011 and 2020. The amount of rainfall varies between 9540 mm and 9590 mm in length. In the northern part of the study area, there is low rainfall ranging from 950 mm to 9550 mm during April to June, while the southern part experiences high rainfall ranging from 9580 mm to 9590 mm between July and September (Figure 2d). From 1983 to 2019, the annual rainfall distribution was recorded at 1071.73 mm (Figure 3). Abundant rainfall can saturate the soil and have the potential to cause flooding.
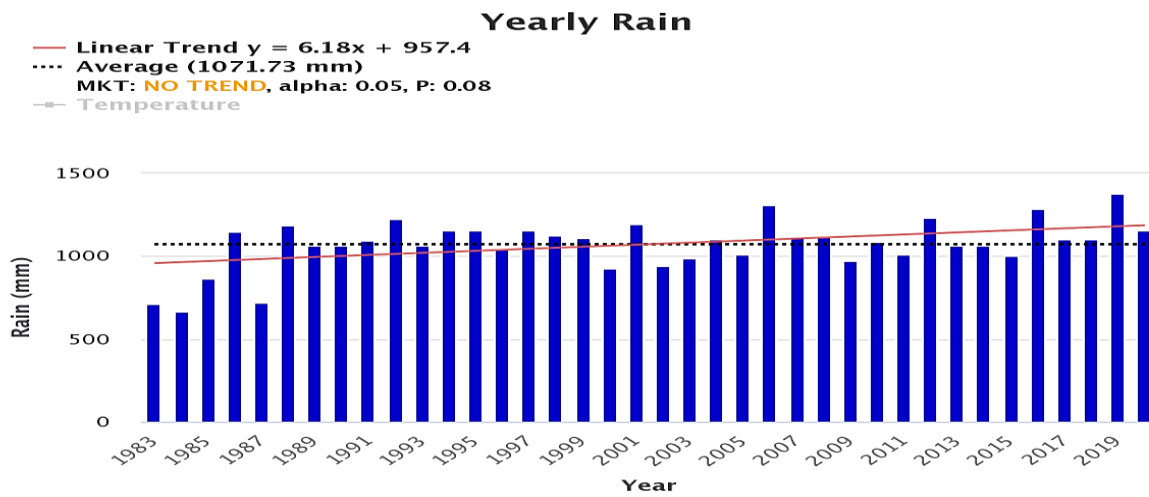
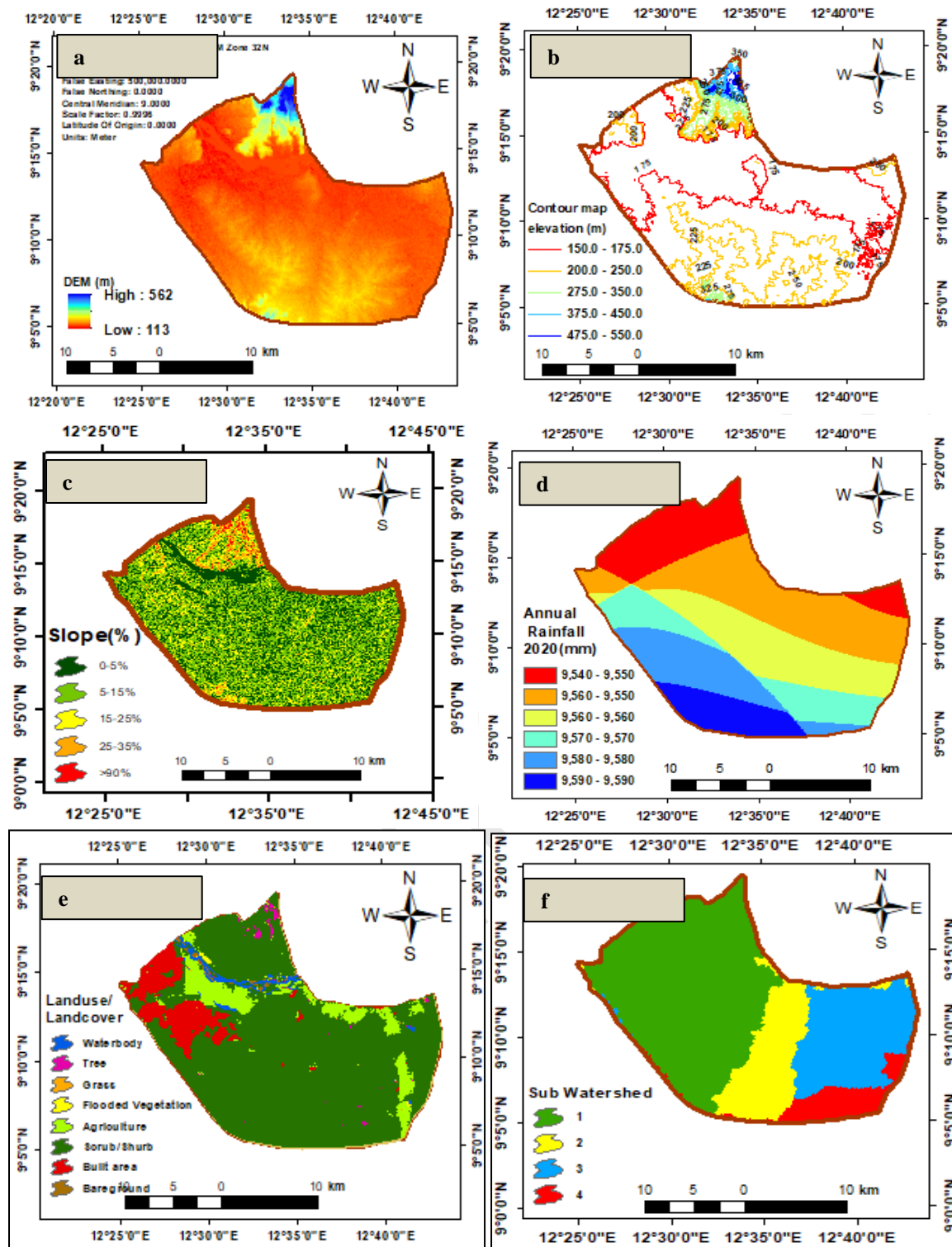**Fig. 3** Annual Rainfall (1983–2019) distribution of Yola catchment area

Fig.3 (a) Digital elevation model of the study area; **(b)** Contour map; **(c)** slope map **(d)** Rainfall **map (e)** LULC map **(f)** Sub watershed map
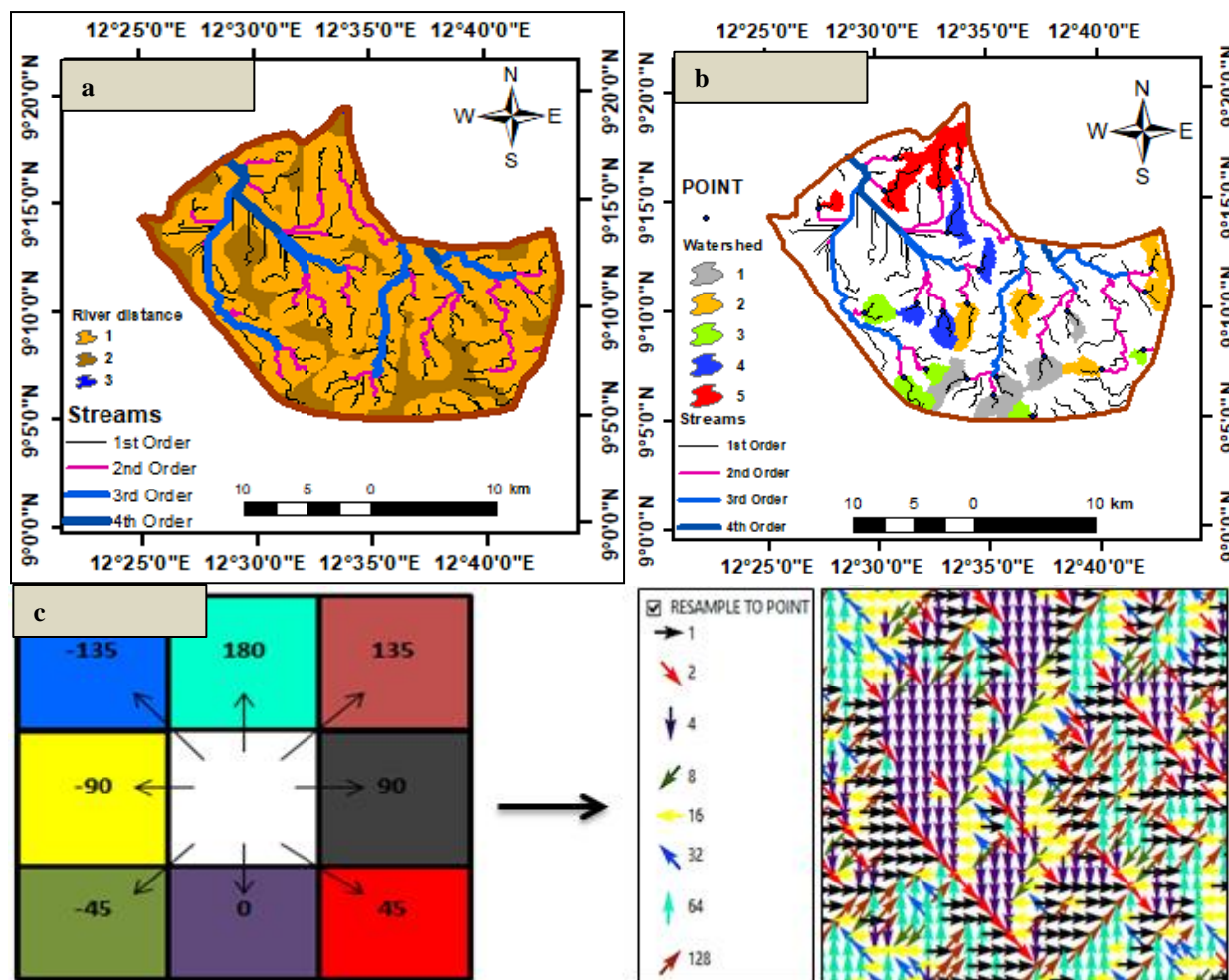
Fig. 4 (a) Stream network order map**; (b)** Basin Watershed **(c)** Flow direction matrix and direction coding

3.8 Flow direction Matrix

Each cell's flow direction is indicated by a value assigned by a direction flow grid. The topographical features determine the orientation of water movement within the cell. Depending on the direction of flow, this stage in hydrological modeling has varying significance. where the water eventually ends up as it travels across the terrain (MaDGIC, 2014). Grids for flow direction are made using the Flow Direction tool. Each set of nine cells, which is composed of a 3x3 grid, has an adjacent cell closest to the center that is determined by the grid processor. For every grid digit, if the central cell flows directly north, the value will correspond to a flow direction below. (**Figure 4c**) shows that if the direction is northeast, the value of 180 will decrease to 135. The elevation values from the underlying DEM are used to determine these numbers, which are only codes that define a particular directional value and have no numerical significance.

4.0 Results and discussion

Table 2. Most Flooodable and less Floodable villages within Yola cathment area

S/No	Most Floodable Villages	S/N Less Floodable Villages	
1	Rugange	1. Modire	10. Wuro Ardo kyari
2	Yolde Pate	2. Takande	11. Gaawi
3	Karewa 1	3 Bachure kofare	12. Parda
4	Tature	4 Karewa 2	13. Wuro Galadimawo
5	Wuro Mallum	5. Yola	14. Bati
6	Rumde Waziri	6. Wuro hausa	15. Bappawo
7	Lakare	7. Lugere	16. Njoboli
8	Rumde Kofa	8. Sabore	17. Gaita
9	Madumari	9. Wuro boki	18. Jalingo
			19. Yola
			20. Wuro hausa

Area= 170.6 km^2 (33.3%)	Area= 130.1 km^2 (25.41%)

4.1 Level Map

DEM (SRTM) data was used to create the flood level map (Figures 5a & 5b) for the research area. Two flood levels were categorized using DEM, namely the more and least floodable areas. Floods can occur in the red zone, which is the floodable area that makes up 33.3% of the study area and covers an area of 170.6 km^2, which affects nine (9) villages in the study area. The less floodable areas, which make up 25.41% of the study area and cover an area of 130.1 km^2, affect twenty (20) villages in the study area.
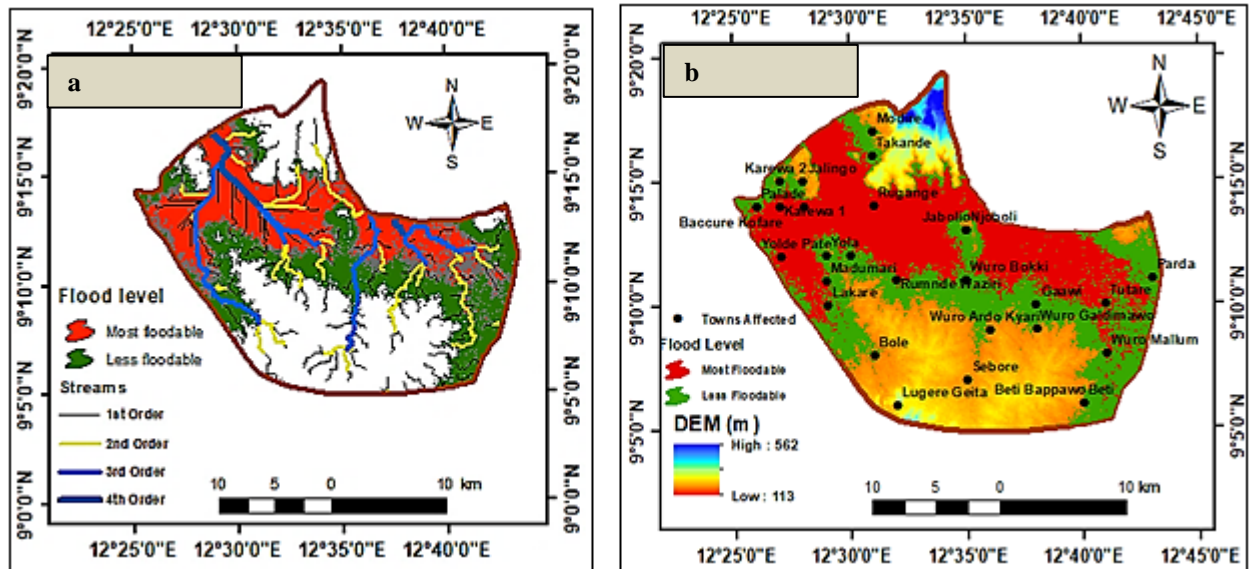

Fig. 5 (a) Flood level with stream channels **(b)** flood level with locations and DEM

5.0 Conclusion

This research utilizes a single Digital Elevation Model (DEM) dataset derived from the Space Shuttle Radar Topography Mission (SRTM). Consequently, it invites researchers to explore alternative DEM sources, such as ASTER v.2 DEM, LiDAR-DEM, GLOBE DEM, and EARTHEnv-DEM90, to validate flood levels within the study region. The flood level map produced in this investigation (Figure 5b) illustrates the current flooding conditions of the area; the DEM was used to categorize flood levels into two groups - The less floodable areas, which make up 25.41% of the study area and the most floodable class covering 33.3% of the area offering essential insights for flood risk management. This information is crucial for prioritizing the development and assessment of regions at high risk. The study employs Geographic Information System (GIS) technology and remote sensing techniques to depict the recent flooding scenario and evaluate its impacts. It contributes to a deeper understanding of the flood event and serves as a reference for establishing effective flood management strategies, aiding governmental and organizational decision-making processes to reallocate resources for the benefit of affected populations. Furthermore, the findings may have significant implications for emergency preparedness, particularly in facilitating aid and relief efforts in vulnerable areas in the future. The generated map can assist relevant authorities in gaining a clearer understanding of the inundation patterns within floodplains, which fall under their jurisdiction for protection and mitigation. Additionally, it aims to enhance public awareness regarding flood imagery, thereby fostering a better understanding of flood risks.

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Sustainable Biopolymer Materials for Defense and Surveillance Applications

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Abstract

The ongoing security challenges in northeast Nigeria underscore the urgent need for innovative and sustainable solutions in defense infrastructure and protective technologies. This paper explores the potential of biobased polymers, derived from renewable resources such as proteins, cellulose, and plant starches, for use in military and security applications. Biobased polymers offer distinct advantages, including superior mechanical properties, thermal stability, and environmental sustainability, making them suitable for protective gear, surveillance equipment, and structural reinforcements. Case studies, such as protein-based shock-absorbing materials and cellulose-derived energetic polymers, demonstrate significant progress in the field. Additionally, advancements in synthesis techniques, including recombinant protein engineering and nanocomposite formation, have expanded the functionality of biobased polymers to meet the stringent demands of defense applications. While challenges related to large-scale production and cost remain, the continued evolution of these materials points to their increasing role in fostering resilient and sustainable defense solutions. This work emphasizes the importance of further research and cross-industry collaboration to harness the full potential of biobased polymers for security applications.

Keywords: Biobased polymers, Defense applications, Sustainable materials, Protective gear and Nanocomposites

1 Introduction

The security challenges in northeast Nigeria, intensified by insurgent activities, inadequate infrastructure, and environmental vulnerabilities, have created an urgent need for resilient, sustainable solutions in defense and infrastructure [1]. Frequent attacks on infrastructure and the region's exposure to harsh climate conditions have further increased the demand for durable, adaptable materials capable of withstanding adverse environments [2]. As conflict continues to destabilize communities, protecting civilians and enhancing defense capabilities has become a top priority for both local and international stakeholders.

While traditional security efforts focus on personnel and technological reinforcements, material science is increasingly recognized as crucial to defense strategies, especially in areas like protective gear, infrastructure reinforcement, and surveillance technology. Advances in this field highlight the essential role of lightweight, high-strength composites and polymer-based materials in protective armor, remote surveillance systems, and transportation, directly enhancing the durability and adaptability of defense operations [3]. However, the materials commonly used—such as metals, ceramics, and synthetic polymers—pose significant environmental challenges. They are often non-biodegradable and reliant on non-renewable resources, making them unsustainable for prolonged use in conflict-prone areas [4].

In recent years, biobased polymers have garnered attention as eco-friendly alternatives for various applications, including medical, packaging, and construction materials, due to their biodegradability, low toxicity, and renewable sourcing [5,6]. Their application in the defense sector, although less explored, shows significant promise. Researchers are investigating the use of biobased polymers for lightweight, durable, and impact-resistant protective equipment and biodegradable casings for surveillance technologies [7,8]. Biopolymers derived from agricultural waste and other local resources present an attractive option for Nigerian defense applications, as they align with sustainability goals and reduce dependency on imported synthetic materials.

Several studies indicate that with appropriate design and processing, biobased polymers can achieve mechanical properties suitable for protective gear, while their biodegradability minimizes the environmental footprint of deployed materials in sensitive areas [9–12]. Moreover, the production of these materials from locally available resources, such as cassava or cocoyam, could create economic opportunities and support community resilience, indirectly contributing to regional security efforts [13,14].

This paper examines the potential for biobased polymers to enhance security efforts in northeast Nigeria through the development of sustainable protective and surveillance applications. By focusing on locally sourced materials and scalable production methods, we aim to provide a blueprint for creating eco-friendly, cost-effective, and resilient materials that meet the unique demands of the region's security landscape.

2. Overview of Biobased Polymers in Defense and Surveillance Applications

Biobased polymers, sourced from renewable biological materials like plant starches, proteins, and lignocellulosic compounds, are gaining momentum as sustainable alternatives to traditional materials across various industries [15]. Recently, these polymers have attracted considerable attention for defense and surveillance applications, where the demand for materials that combine effectiveness with environmental responsibility is high [16]. This section examines recent advancements in biobased polymers as applied to protective gear, surveillance devices, and structural reinforcements in defense contexts.

Notable studies have underscored the potential of biobased polymers in defense. Research on polymer-based nanocomposites, for example, reveals their suitability for defense materials, offering enhanced mechanical strength, electrical conductivity, and thermal resilience critical for military applications [16]. Collaborative efforts, such as those between Cambium Biomaterials and the U.S. Navy, have further led to the development of biobased, fire-resistant composite materials for aerospace and space transport, addressing advanced material needs in these fields [17].

Additionally, the biodegradability and sustainability of biobased polymers make them especially attractive for defense and surveillance applications, where reducing environmental impact is crucial. Reviews on bio-based sustainable polymers highlight their potential to lower dependency on non-renewable resources and align with ecological goals in defense settings [12]. These developments demonstrate a growing interest in biobased polymers for use in protective gear, surveillance systems, and structural reinforcement, driven by the need for materials that meet both functional and environmental criteria.

2.1 Protective Applications

The defense sector has long relied on materials that are durable, lightweight, and resistant to high-impact forces for use in protective equipment, such as helmets, body armor, and shields. Traditionally, these needs have been met using metals and synthetic polymers, which, although effective, are resource-intensive and often non-biodegradable. Recent studies indicate that biobased polymers can be engineered to meet stringent defense requirements while offering sustainability benefits, such as biodegradability and reduced environmental impact [18].

Biopolymer composites, particularly those reinforced with natural fibers, have shown significant promise in protective applications. For instance, cellulose-reinforced polylactic acid (PLA) composites have been identified as a viable alternative for high-strength, lightweight body armor [19]. PLA, a biopolymer derived from corn starch, is known for its high mechanical strength and low density, making it suitable for protective applications. Additionally, incorporating natural fibers, such as kenaf or flax, into PLA matrices improves impact resistance and flexibility, essential qualities for body armor and helmets [20].

Moreover, polyhydroxyalkanoates (PHAs), another class of biobased polymers, have gained attention for their durability and biodegradability. Recent research indicates that PHA composites can be used in ballistic protection due to their high tensile strength and ability to absorb impact energy [21]. Their biodegradability makes them an ideal choice for temporary protective installations, particularly in conflict zones where waste management systems are often limited [22].

2.2 Surveillance and Sensor Technologies

Surveillance systems are essential components of modern defense strategies, enabling real-time monitoring of conflict zones and enhancing situational awareness. The use of biobased polymers in surveillance and sensor applications is an emerging field that focuses on materials for sensor casings, lightweight drone bodies, and biodegradable camouflage coatings [10,23]. These materials not only provide durability but also minimize environmental impact, an important consideration when deploying equipment in ecologically sensitive areas.

Biopolymers such as polylactic acid (PLA) and poly(butylene succinate) (PBS) have shown potential in constructing lightweight and durable drone structures. PLA is valued for its ease of processing, and drones constructed with PLA frameworks have demonstrated satisfactory performance in surveillance applications, particularly in high-risk zones where equipment recovery may be challenging. Biodegradable sensors housed in PBS casings have been successfully field-tested in remote sensing applications, showing durability in harsh environments while reducing waste accumulation once they are no longer in use [24–26].

Camouflage and stealth technologies also benefit from biobased polymers, as these materials can be engineered to blend seamlessly with natural surroundings while degrading after use. For instance, PLA and lignin-based films have been developed as environmentally friendly, disposable camouflage materials. Studies show that incorporating biodegradable biopolymers in camouflage materials can significantly reduce the ecological footprint of military activities in sensitive regions [10,27].

2.3 Case Studies of Biobased Polymers in Defense Applications

Recent advancements in the use of biobased polymers have demonstrated their substantial potential in military and defense applications. These case studies highlight how innovative biopolymeric materials are addressing the limitations of traditional materials and opening new pathways for defense technologies.

One remarkable example involves the development of *talin shock-absorbing materials* (TSAMs). Research led by Doolan et al.[28] showcased TSAMs created from recombinant forms of the mechanosensitive protein talin. This protein-based material was engineered to crosslink into a monomeric unit capable of exceptional energy dissipation. In tests involving 1.5 km/s supersonic impacts, TSAMs not only absorbed the energy effectively but also captured and preserved projectiles, presenting significant advancements over current ballistic armor, which often faces limitations in weight, breathability, and durability. This research underscores the promise of biopolymer applications in producing next-generation protective gear that is both lightweight and highly effective.

In another study, Tarchoun et al. [29] focused on synthesizing a new class of *high-energy dense biopolymers* using nitrogen-rich functional groups, specifically 1H-tetrazol-1-yl acetate and nitrate esters derived from cellulose and its micro-sized form. The synthesized biopolymers, named TNCN and TCMCN, exhibited superior performance metrics, including densities of 1.710 g/cm³ and 1.726 g/cm³, nitrogen contents of 20.95% and 22.59%, and detonation velocities of 7552 m/s and 7786 m/s, respectively. These materials also demonstrated impressive thermal stability and insensitivity to mechanical shocks, marking them as potential candidates for replacing conventional nitrocellulose-based energetic materials. This innovation represents a significant stride in developing safer, high-energy biopolymer-based explosives that align with the sustainability and safety needs of modern defense operations.

Additionally, the exploration of biopolymer-based matrices in optical technologies has shown potential in security and surveillance systems. Sznitko et al. [30] conducted experiments on amplified spontaneous emission (ASE) and random lasing using various luminescent organic molecules embedded within biopolymeric matrices such as poly(methyl methacrylate), poly(N-vinyl carbazole), and polycarbonate. The study revealed that these biopolymer-based matrices could effectively host active dye molecules, contributing to the advancement of lasing technologies with lower degradation rates and improved photostability. Such developments are critical for optical and surveillance devices used in defense, where reliability and longevity are paramount.

These case studies collectively illustrate the transformative potential of biobased polymers in military applications. From energy-absorbing protective materials and environmentally safer high-energy explosives to enhanced optical systems, biobased polymers are proving to be versatile, sustainable, and highly effective in meeting the complex demands of modern defense technologies.

3. Material Selection and Synthesis of Biobased Polymers for Security Applications

The development and utilization of biobased polymers for security and defense applications necessitate a comprehensive understanding of material selection criteria, synthesis methodologies, and performance characteristics. This section explores the critical factors in choosing suitable biobased polymers and the advanced synthesis techniques employed to meet the stringent requirements of security applications.

3.1 Material Selection Criteria for Biobased Polymers

Choosing the right biobased polymer for security purposes involves evaluating several essential properties to ensure efficacy and durability in harsh environments. Key criteria include:

1. **Mechanical Strength and Durability**: Defense materials must withstand extreme mechanical stresses, such as ballistic impacts or high-pressure scenarios. Polymers like cellulose derivatives, polylactic acid (PLA), and protein-based materials have shown promise due to their ability to be enhanced through composite formation. For instance, cellulose-based composites reinforced with nanomaterials exhibit high tensile strength and toughness, making them suitable for protective armor [31].
2. **Thermal Stability**: Materials used in defense often encounter high temperatures, especially in applications involving explosive resistance or thermal shielding. Biobased polymers must possess or be modified to exhibit multi-step thermal decomposition, ensuring stability under such conditions. Cellulose nitrates, chemically modified to improve thermal performance, exemplify materials with superior thermal decomposition properties [31].
3. **Environmental Impact**: The sustainability aspect is integral to material selection, particularly for military operations where long-term ecological consequences are considered. Biobased polymers derived from renewable sources, such as starch, lignin, and proteins, offer an eco-friendly alternative to traditional synthetic polymers. This shift reduces reliance on fossil fuels and mitigates environmental hazards associated with non-biodegradable waste[32].
4. **Adaptability and Versatility**: The capacity for customization is essential for security applications that may demand unique material properties. Biopolymers with modifiable chemical structures, such as those based on protein sequences or cellulose derivatives, allow for tailored mechanical, optical, and thermal properties [33].

3.2 Synthesis Techniques for Biobased Polymers

The synthesis of biobased polymers tailored for security applications involves advanced techniques designed to optimize their physical and chemical properties. Some of the notable synthesis approaches include:

1. **Polymerization and Crosslinking Techniques**:

   a. **Recombinant Protein Synthesis**: Proteins engineered for specific functions, such as talin, are synthesized through recombinant DNA technology. This method enables the production of high-purity, tailored proteins that can be crosslinked to create materials with exceptional energy-dissipation properties, as demonstrated by the development of talin shock-absorbing materials [34].
   b. **Ring-Opening Polymerization (ROP)**: This method is widely used for synthesizing polylactic acid (PLA) and other biodegradable polymers. ROP ensures the controlled polymerization of monomers, yielding high-molecular-weight polymers suitable for defense coatings and protective layers [35,36].

2. **Functionalization and Chemical Modifications**:

   a. **Nitration and Acetylation of Cellulose**: The chemical modification of cellulose through nitration and acetylation results in derivatives like nitrocellulose, which possess enhanced energy density and explosive capabilities. Such modifications also improve mechanical sensitivity, making them safer alternatives for explosive formulations [29].
   b. **Grafting Techniques**: Grafting functional groups onto a polymer backbone is a common method to introduce properties such as flame retardancy and impact resistance. This technique is used to create composites that maintain the inherent biodegradability of the base polymer while providing additional security features[37].

3. **Nanocomposite Formation**:

   a. **Incorporation of Nanomaterials**: Integrating nanoparticles, such as graphene oxide or carbon nanotubes, into biobased polymers can significantly enhance mechanical strength, electrical conductivity, and thermal resistance. These composites have applications in the fabrication of lightweight body armor and electronic surveillance equipment [38,39].

    b. **Sol-Gel Processing**: This synthesis method facilitates the development of hybrid organic-inorganic materials by embedding biopolymers with metallic or ceramic nanoparticles. The resulting composites exhibit increased durability and protective capabilities [40].

4. **Advanced Processing Methods**:

    a. **Electrospinning**: Electrospinning is used to create ultra-thin polymer fibers with high surface area-to-volume ratios. These fibers can be incorporated into body armor and filtration systems, offering a lightweight yet robust layer of protection. Electrospun biopolymer fibers have demonstrated promising ballistic resistance when combined with nanoparticles or crosslinked proteins[41].

    b. **3D Printing and Additive Manufacturing**: The advent of 3D printing has enabled the precise fabrication of biopolymer structures with customizable shapes and properties. This approach is particularly beneficial for creating personalized protective equipment and complex structural reinforcements for defense applications [42].

3.3 Challenges and Opportunities

While biobased polymers present exciting opportunities for defense applications, challenges such as scalability, cost, and long-term performance remain. The synthesis of biopolymer composites often involves complex and resource-intensive processes, which can hinder widespread adoption. However, continued research into cost-effective production methods and sustainable sourcing can mitigate these challenges.

Opportunities for future developments include the exploration of biopolymers with self-healing properties, the incorporation of responsive materials that adapt to environmental stimuli, and the use of green chemistry principles to enhance environmental compatibility. Additionally, fostering collaborations between academia, industry, and military research bodies will be essential for the successful integration of biobased polymers into security applications.

Conclusion

The use of biobased polymers in defense and security applications presents an innovative approach that aligns with the growing need for sustainable and high-performance materials. The synthesis and material selection processes explored in this paper demonstrate that biobased polymers, derived from renewable resources such as proteins, starches, and cellulose, offer significant potential for addressing the complex challenges faced in military settings. These materials provide distinct advantages in mechanical strength, thermal stability, and environmental responsibility, essential for protective gear, surveillance technologies, and structural reinforcement.

Despite these promising developments, challenges remain in terms of large-scale production, cost-effectiveness, and ensuring long-term durability under field conditions. Addressing these barriers through continued research, collaboration between industries, and the adoption of green chemistry practices will be pivotal in realizing the full potential of biobased polymers in defense applications. Future opportunities include the incorporation of self-healing and stimuli-responsive properties, which could revolutionize the resilience and functionality of defense materials.

Overall, the integration of biobased polymers into security applications signifies a transformative shift toward materials that balance performance with sustainability. The research and advancements discussed in this paper underscore the need for ongoing innovation and strategic partnerships to push the boundaries of material science in safeguarding military personnel and infrastructure. As biobased polymer technologies continue to mature, their role in fostering more sustainable, resilient defense systems is poised to grow, offering long-term benefits for both security and environmental stewardship.

In conclusion, the selection and synthesis of biobased polymers for security applications involve a multidisciplinary approach that leverages advancements in polymer chemistry, nanotechnology, and sustainable engineering. The continued evolution of these materials holds significant promise for developing environmentally responsible, high-performance solutions that meet the rigorous demands of modern defense.

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