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2. **Materials and Methods**
3. **Results and Discussion**
4. **Conclusion**
5. **References**

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Introduce and present results inform of frequency tables, pie charts, graphs and proceed to discuss them with literature.

4. Conclusion

In the conclusion section, besides wrapping up the research by reiterating the goal of the study and confirm the major results or outcomes and concrete recommendations be offered, some limitations of the current study can be reported. The authors should discuss these limitations from which research directions for future studies may be offered.

5. References

1. **References for research articles**
   A. N. Ikot, L. F. Obagboye, U. S. Okorie, E. P. Inyang, P. O. Amadi, I. B. Okon, Abdel-Haleem Abdel-Aty, *European Physical Journal Plus* 137(2022) 1370**.**
2. References **for published/conference proceedings**:

Kapitsaki GM. Reflecting user privacy preferences in context-aware Web Services. Department of Computer Science University of Cyprus Nicosia, Cyprus. In: Proceedings of the IEEE 20th International Conference on Web Services. 2013. https://doi.org/10.1109/ICWS.2013.26

3 **References for Books**

M. Abramowitz and I. A. Stegun, *Handbook of Mathematical Functions with Formulas, Graphs, and Mathematical Tables* (Dover, New York, 1972). Pp. 23-37.

4 **References for Book Chapter**
Halpen-Felsher BL, Morrell HE. Preventing and reducing tobacco use. In: Berlan ED, Bravender T, editors. Adolescent medicine today: a guide to caring for the adolescent patient [Internet]. Singapore: World Scientific Publishing Co.; 2012 [cited 2019 Nov 3]. Chapter 18. Available from: https://doi.org/10.1142/9789814324496_0018

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Australian Medical Association [Internet]. Barton ACT: AMA; c1995-2012 . Junior doctors and medical students call for urgent solution to medical training crisis; 2012 Oct 22 [cited 2019 Nov 5]; [about 3 screens]. Retrieved

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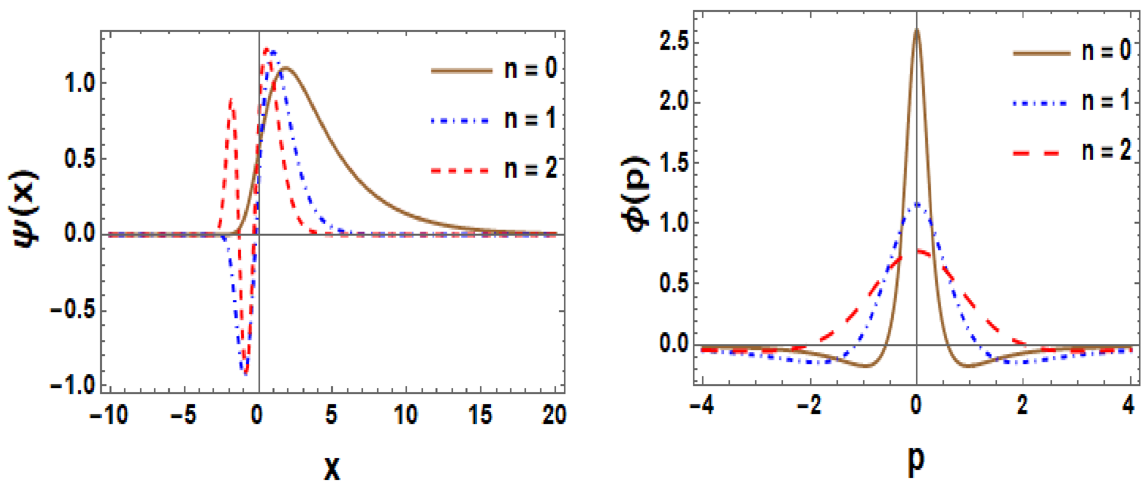

Figure 1: Wave function of the Position and Momentum spaces of shifted Morse Potential for ground, first and second excited states.

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Tables should be included in the manuscript document and must be cited in the text. All tables should have a concise title and written as Table 1 as shown below:

Table 1: Numerical values of energy eigenvalues $(-E_n)$ of shifted Morse Potential, where

$A = 0.1, D_e = 0.02, \alpha = 0.8,\ m = 1.0,\ \hbar = 1.0$

n	$A = 0.1,\ B = 1.0$	$A = 0.1,\ B = 1.5$	$A = 0.1,\ B = 2.0$
0	0.02396851613	0.02912952290	0.03235477070
1	0.5922741755	0.6103990945	0.6214088670
2	1.800579835	1.831668666	1.850462963
3	3.648885494	3.692938237	3.719517059
4	6.137191155	6.194207810	6.228571155
5	9.265496815	9.335477380	9.377625250
6	13.03380248	13.11674696	13.16667934
7	17.44210813	17.53801652	17.59573344
8	22.49041379	22.59928610	22.66478754
9	28.17871946	28.30055567	28.37384164
10	34.50702509	34.64182528	34.72289571

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Conventional Streamer Data De-Ghosting Using Frequency Varying Reflection Coefficient For An Improved Deconvolution

Paula Ukerun; Syvelster Ugwu and Rasaki Salami

Abstract

In this study, we present the benefits of applying source and receiver sides ghost removal within optimized frequency bands. The occurrence of multiples in the seismic signal limits the resolution of seismic events. In most conventional seismic surveys, short period multiples are generated from downward reflections of seismic waves by the sea surface on the source and receiver sides; with a reflection coefficient close to -1, which varies with the angle of incidence. Using data derived de-ghosting operators can improve signal resolution and seismic bandwidth for a more accurate subsurface imaging.

The data used in this research had a nominal source depth of 5m and receiver depth of 8m, giving a source and receiver notch frequencies of 150Hz and 94Hz respectively. Deconvolution in the F-K (Stolt) migration domain showed an improvement in signal resolution with the removal of the source and receiver sides generated short period multiples. Higher refection coefficient estimation for the ghosts improved the low frequency signal recovery with potential loss in high frequency signal quality. To optimize the signal to noise ratio over the frequency range, frequency varying reflection coefficients were used in data de-ghosting in a novel approach; the improved quality of the de-ghosted data indicate a dependence between of the reflection coefficient of the ghost operation and the frequencies.

Keywords: Conventional Streamer Data, Varying Reflection Coefficient, Improved Deconvolution,

Introduction

Source and receiver side ghosts are short period seismic multiples of primary reflections rebounded off the free surface at the source and receiver side during marine seismic acquisition (Figure 1). Up-going seismic waves are reflected downward by the sea surface with near -1 reflection coefficient. (Zhou et. al, 2012, O'Driscoll et. al, 2013). This would indicate that the ghost energy is predicted to have the same (inverse) amplitude as the primary signal. However, the reflection coefficient changes with angle of incidence (Yilmaz, 2001). Many conventional streamer data are acquired with source- and receiver-side ghosts reflecting off the free surface, reducing signal resolution and processing bandwidth through constructive and destructive interferences with the desired primary signals.

De-ghosting processes (used in this study refer to the removal of both receiver and source side ghost reflections from the sea surface) can be applied to conventional streamer data acquired with single component streamers (Zhou et. al, 2013). In this study data-driven approach was used to derive the de-ghosting operators for deconvolving the recorded reflections off the water layer at the source and receiver sides. The applied de-ghosting method uses a non-linear optimization to derive a stable operator which, when applied to conventional marine streamer seismic data, recovers much of the signal present in the recorded data, but weakened by the presence of the ghosts at the notch frequencies (O'Driscoll et. al, 2013).

As the P-wave travels through rock, its amplitude decay due to effective Q as a function of frequency and travel time. As it travels through a rock / medium, the higher frequencies have more cycles than the lower frequencies and are more attenuated (Futterman, 1962). This may indicate that a lower Reflection Coefficient (RC) is required to improve de-ghosting results at higher frequencies by the use of varying Reflection Coefficient across the frequency range as demonstrated in this study.

The bandwidth of recorded seismic data is typically between 2-250Hz and is limited in conventional streamer data by the presence of both source and receiver ghost notches. The source and receiver ghost reflections can be predicted using the depths and the near surface water velocity; and their cycles can be identified as notches in the amplitude spectrum. Absorption (Q) is another wavelet distortion factor that can be compensated for to recover the spectrum of conventional streamer data during seismic data processing.

In this paper we present the benefit of applying de-ghosting at targeted frequency intervals versus the application of de-ghosting across all frequencies.

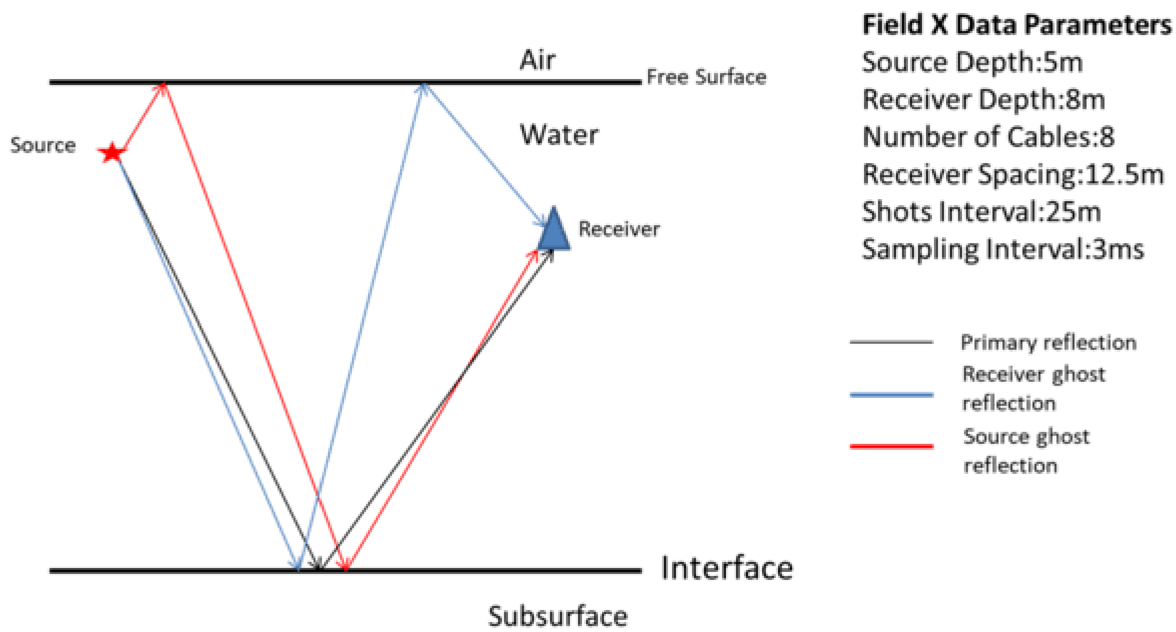

Figure 1 Cartoon illustration of receiver and source ghosts generation

Literature Review

De-ghosting techniques have become integral in enhancing the quality and interpretation of seismic data. Various methods have emerged, particularly in broadband seismic imaging, to mitigate the issues related to receiver and source ghost notches. These techniques often require non-traditional data collection methods, such as specialized marine cables and unique geometries. These approaches have proven to be more effective in dealing with ghost notches compared to conventional methods.

A study by Ross O'Driscoll et al. (2013) in the Gulf of Guinea, used data from an offshore field to test a method described by Zhou. The goal was to obtain high-resolution, broadband seismic images, preserve frequency content up to 90Hz, and ensure the accuracy of seismic amplitudes after processing. De-ghosting was applied to counteract the interference caused by varying depths of acquisition. The results demonstrated good signal preservation and the recovery of higher frequencies, improving data quality.

Further research by processing (Zhou et al. 2013 and Payne et al. 2015), showcased the effectiveness of de-ghosting techniques in co-processing traditional streamer data with varying depths of acquisition. These methods not only improved data matching but also expanded the bandwidth of traditional seismic data.

De-ghosting also played a crucial role in time-lapse (4-D) seismic processing, providing better repeatability and interpretation. It helped to minimize acquisition discrepancies and improve the accuracy of reservoir monitoring (Agnisola et al., 2019). Additionally, de-ghosting was instrumental in enhancing velocity model development, leading to a better understanding of reservoir architecture and improved reservoir models (Chigbo et al. in 2021).

In summary, de-ghosting techniques have proven to be indispensable in seismic data processing, offering benefits in broadband imaging, data matching, reservoir monitoring, and velocity model development.

Methodology

The seismic data used in this study was acquired using a single component streamer on a producing field in deep-offshore Nigeria, the streamer configuration is shown in (Figure 2). The nominal source and receiver depths of the acquisition are 5m and 8m respectively. The expected ghost notches from these depths are 150Hz and 94Hz for the source and receiver side ghosts at a water velocity of 1500m/s. However due to resampling to 3ms and applying a high-cut filter (HC) (120Hz, 72dB / OCT) to the data; the districting source notch is not very apparent. Also, variation of receiver depth between 6-10m from the nominal receiver depth of 8m, with most values between +/- 0.5m of nominal depth, caused a variation of the receiver notch in the frequency-amplitude spectrum ranging between 88Hz and 100Hz (Figure 2). The value of the source depth header was constant at 5m.

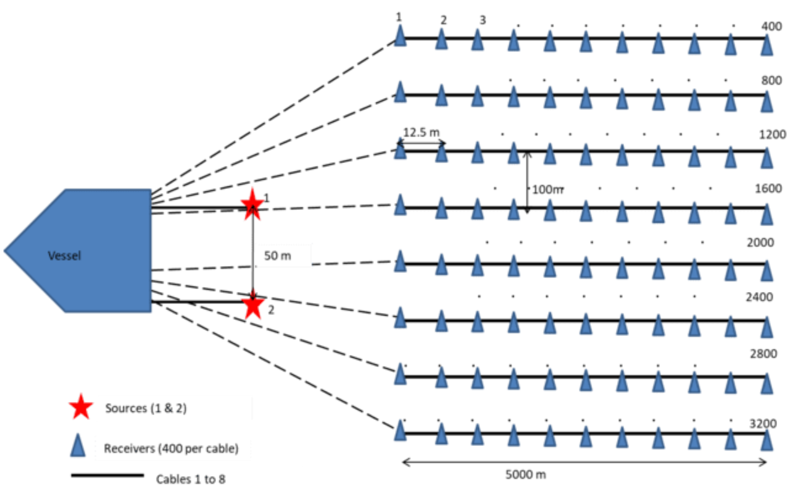

Figure 2 Cartoon representation of acquisition spread of research data based on SEGY header information

It is important that the data is sufficiently free of random and coherent noise bursts prior to de-ghosting to avoid boosting of noise during the deconvolution process. The success of data-driven de-ghosting has enabled many conventional streamer data to be reprocessed for better reservoir imaging and velocity model building (Agnisola et. al, 2019; Chigbo, et. al, 2021). The data used in this study has undergone couple of preprocessing steps as well as various noise attenuation processes (Table 1) and has been resampled from 2ms to 3ms, giving a Nyquist frequency of about 167Hz with a HC filter applied (Figure 3).

Table 1 Key steps of preprocessing applied to input data

- 3Hz, 18dB / Oct Debias filter
- Gun/cable statics correction (8.4ms), TAR^2
- Despike and Trace edits
- Tidal Statics correction
- 120Hz, 72dB / OCT TAAF and 3ms resample
- Swell and Linear noise attenuation (multiple passes and domains)
- Amplitude destripping (shot and channel)
- Residual denoise
- Spatial anti alias filter
- Receiver Moveout Correction
- Water column and cold water statics correction
- 3-D SRME

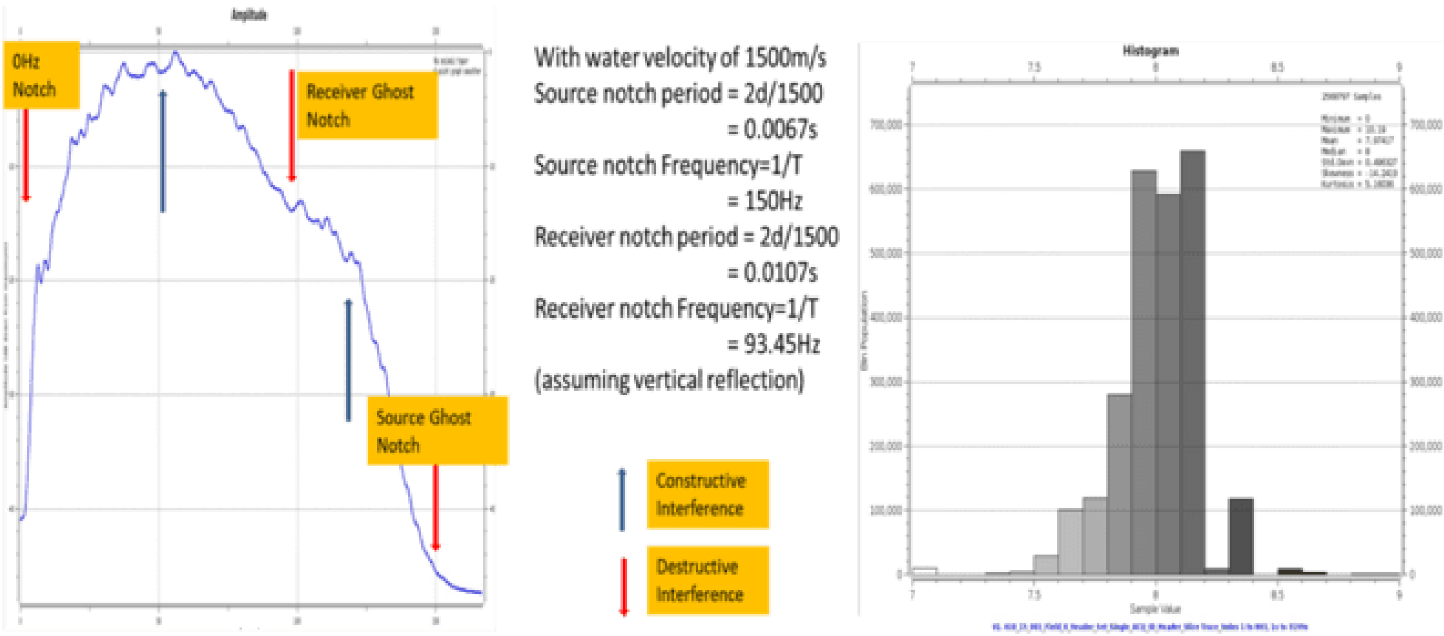

Figure 3 Amplitude spectrum of input data with constructive peaks and destructive notches caused by source and receiver side ghosts interferences (Left). Right is histogram of receiver depths.

De-ghosting was applied to shot gathers using wave equation (Stolt) migration in the frequency domain which helps to remove the angular dependency of the ghost period as convolutional model is based on 1D assumption (Yilmaz, 2001) (Figure 4). The migration scheme uses a 2D Fourier transform in both temporal and spatial domain; by using the full scalar wave equation in the conjugate space, the method eliminates (up to aliasing frequency) dispersion altogether (Stolt, 1978). The measured energy of the data-derived ghost is determined by the estimated reflection coefficient of the ghost used in the deconvolution. The gun and cable statics were backed off before the de-ghosting process.

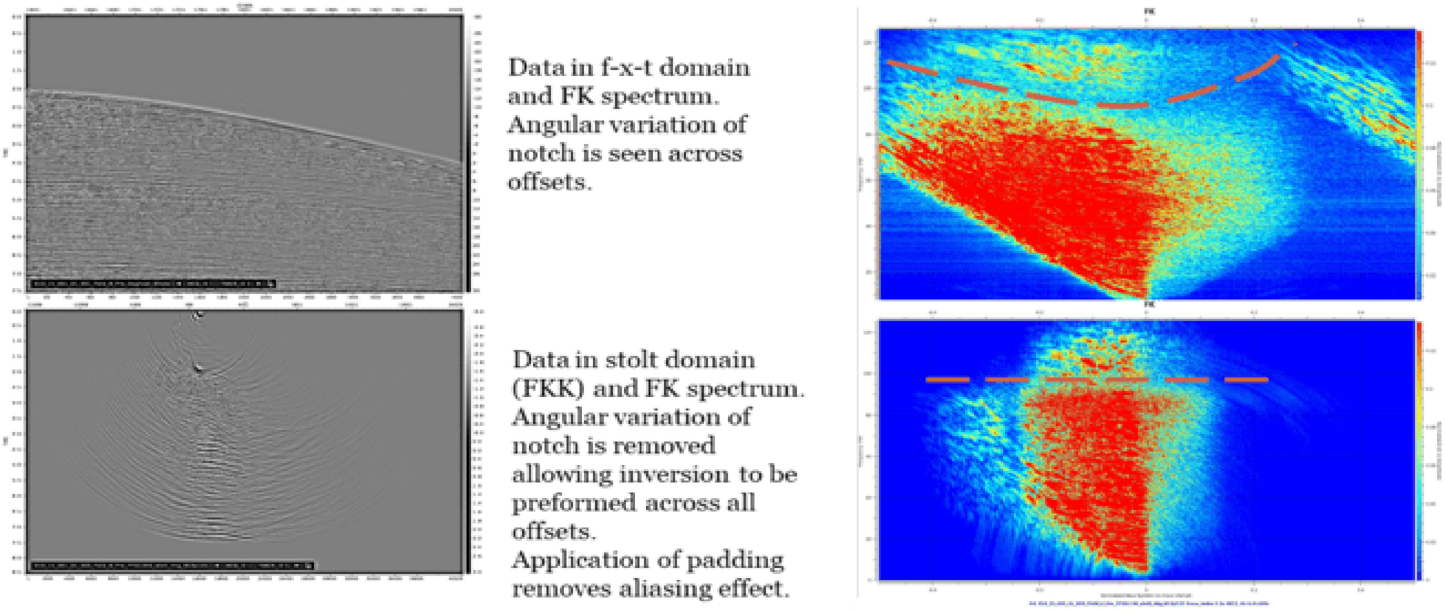

Figure 4 Data in f-x-t domain (above) and FKK domain (below). De-ghosting is done in the FKK domain where the near to far offset is better aligned for improve deconvolution of ghost energy

Using a procedure not known to have been previously used in any documentation of data de-ghosting, tests were performed to optimize the estimate of the RC of the spirit energy to ensure an optimal subtraction of the ghost energy without overestimation that would cause artifacts to develop. Seven initial tests results using different ranges of Reflection coefficient (RC) estimate for the source and receiver ghost were compared (Figure 5, Table 2 left). From the shot and channel gathers analysis, the low frequency content of the data appeared to be improved with increasing RC, while the higher frequency content appeared more stable with lower RC. It was observed that Tests 3, 4 and 5 gave the best results; with improved low-frequency content in test 5 and evidence of data stability at higher frequency in test 3 and 4 (Figure 6 and 7). To optimize the observed improvement in the de-ghosting across Test 3 through 5, varying bandwith de-ghosting was tested using parameters shown in Table 2 right.

Table 2 Reflection Coefficient test range for single RC in Tests 1 – 7 (left) and using varying Reflection Coefficient at varying frequency bands (right).

Test #	**Receiver Ghost**	**Source Ghost**
1	3-4	4-5
2	4-5	5-6
3	**4-5**	**6-7**
4	**5-6**	**6-7**
5	**6-7**	**7-8**
6	7-8	8-9
7	8-9	9-1

Frequency (Hz)	**Rec. Ghost**	**Source Ghost**
0-0-10-15	0.7 – 0.8	0.7 – 0.8
10-15-70-80	0.4 – 0.5	0.5 – 0.6
70-80-160-180	0.5 – 0.6	0.6 – 0.7

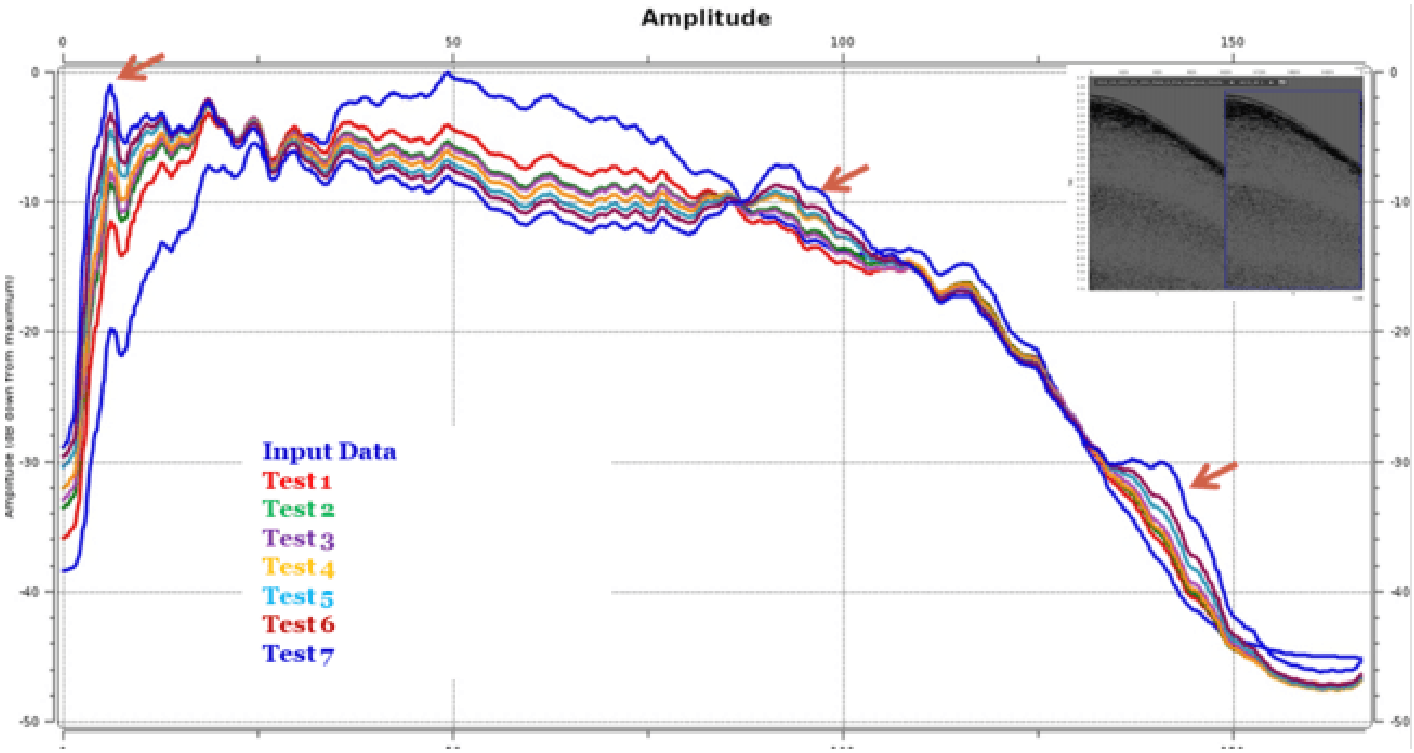

Figure 5: Amplitude spectra of shot gathers from Tests 1 -7. Spectrum at lower frequency appears boosted with increasing RC while the amplitude spectrum appears more distorted with increasing RC estimation (arrow indication Test 7 spectrum).

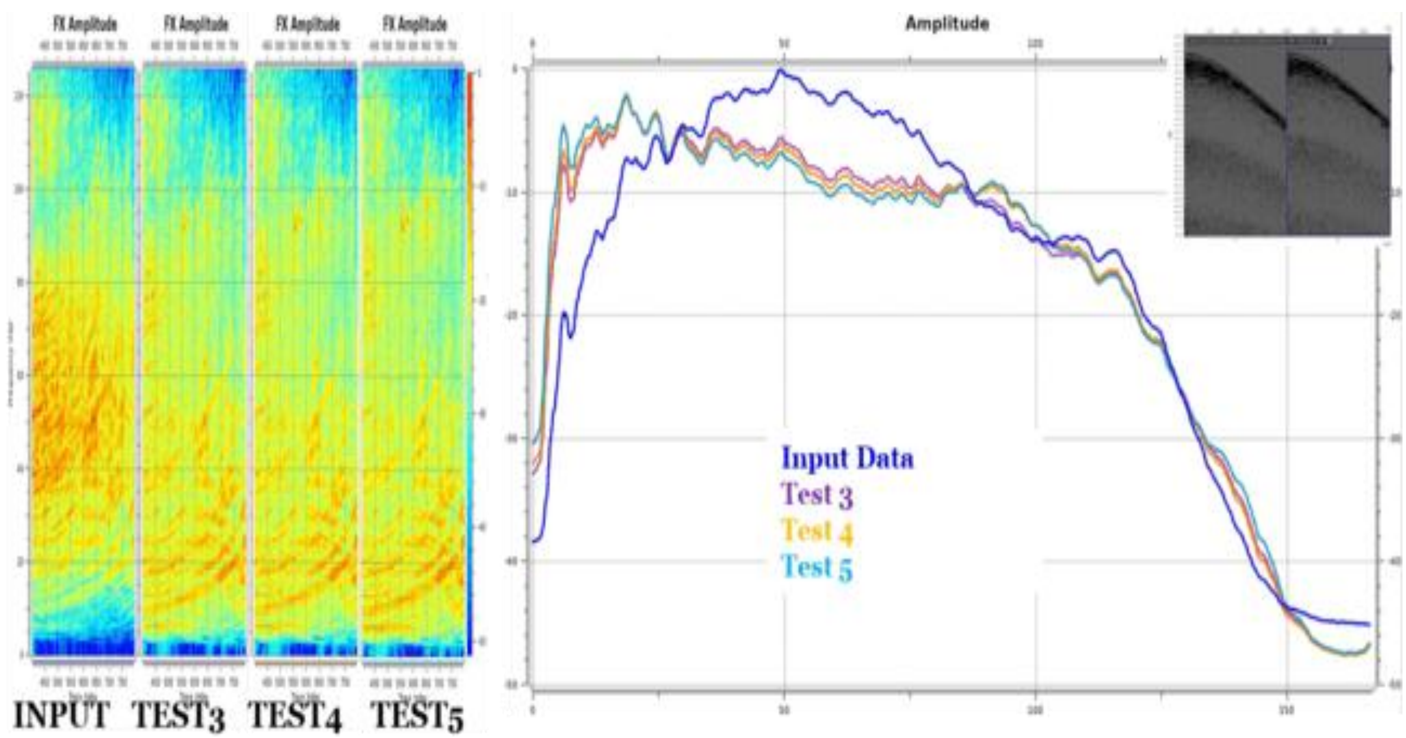

Figure 6 FX and amplitude spectra of Test 3, 4 and 5 shot gathers.

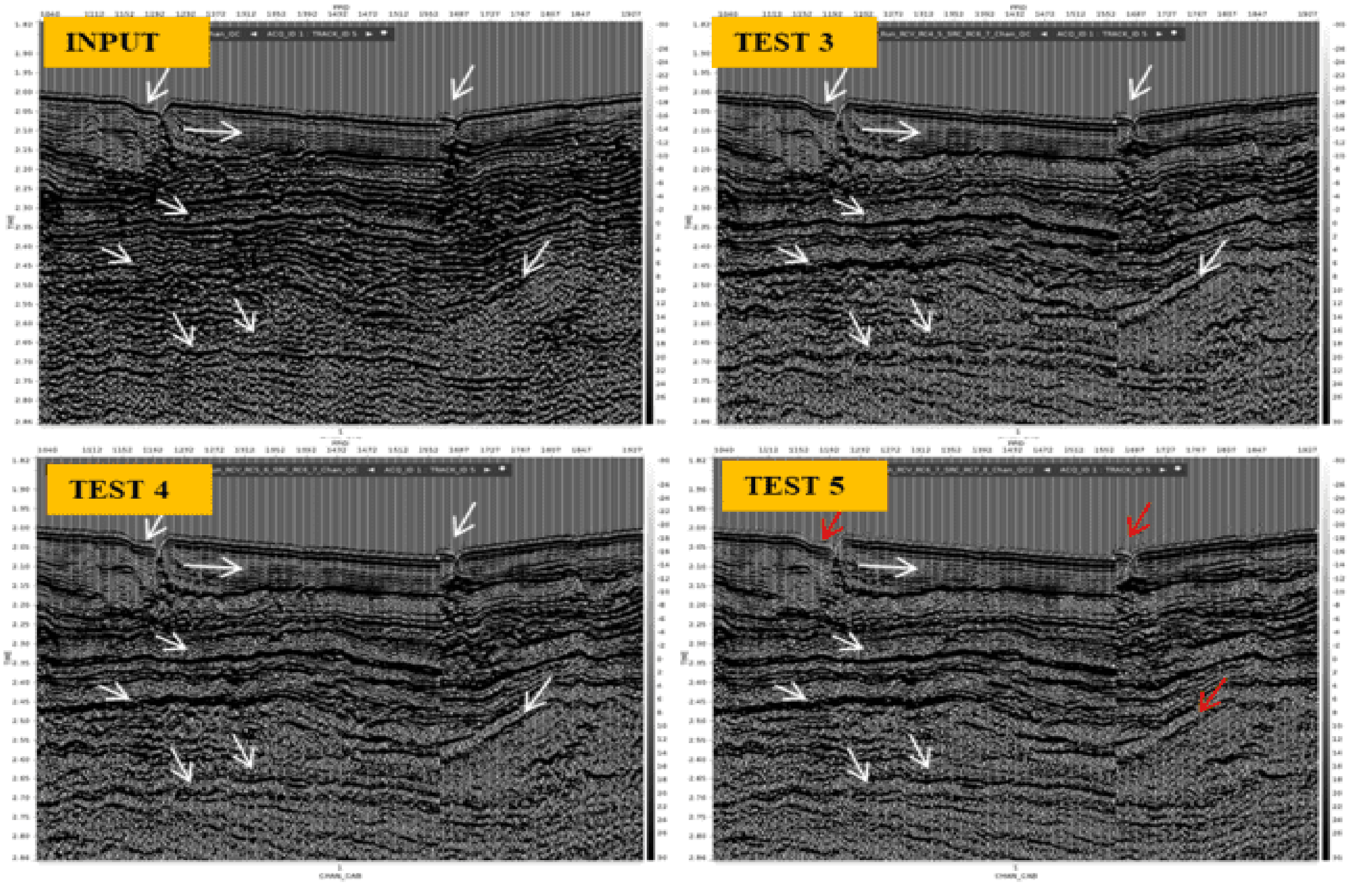

Figure 7: Near Channel Gathers of Tests 3 – 5. Low frequency seen to improve with higher RC estimation but higher frequencies signals appear less optimal (red arrows) with increasing RC estimation

Result

The results from Test 4 and 5 were compared to results from using varying RC across the frequency range (Test 8). Shot gathers QC of Test 4, Test 5 and Test 8 (Figure 8) showed improvement in the data from low to high frequency. Using Test 8 with varying RC across frequency range appears to show best improvement in the low to high frequency signal.

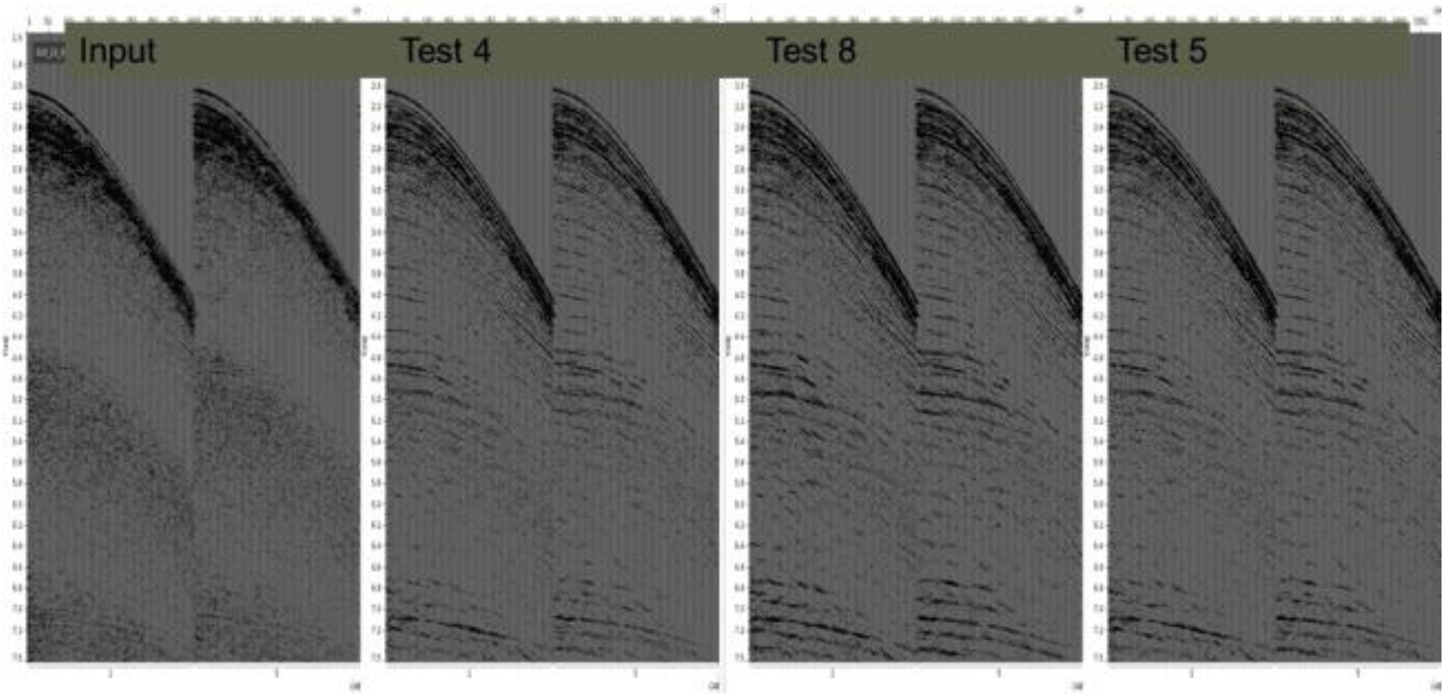

Figure 8: Shot gathers of data before and after de-ghosting. Signal appears more enhance with use of Test 8 varying RC across the frequency range

Analysis of near-channel gathers show correction of possible high frequencies near-surface phase distortion (observed in Test 5) using the frequency variable RC of Test 8 (Figure 9). The near channel gathers FK spectra showed the absence of aliased energy observed in Test 5 due to high RC indicating that frequency varying RC is better able to handle ghost removal properly across all the observed frequencies (Figure 10).

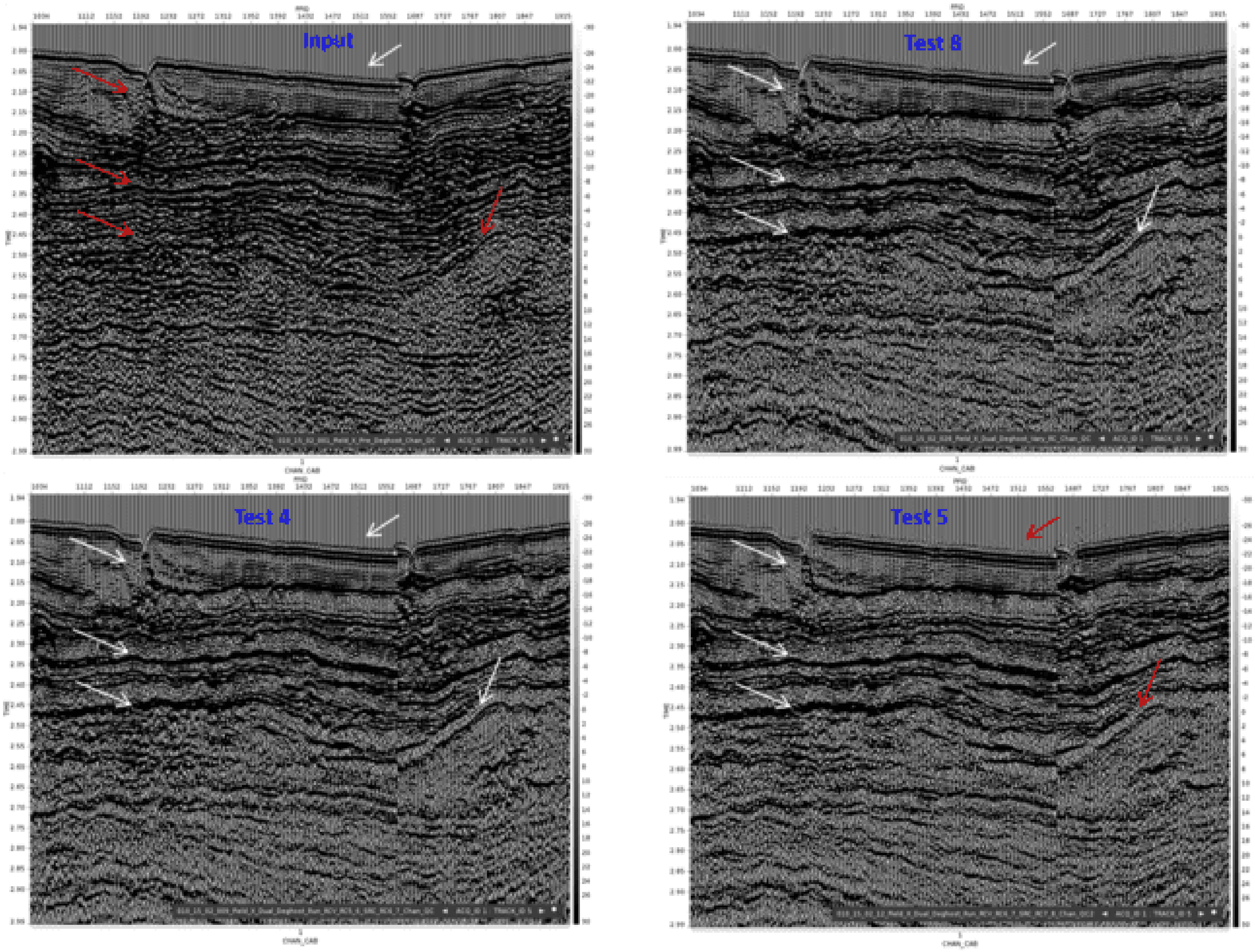

Figure 9: Near Channel gathers displays appears to show correction of phase distortion of higher frequencies observed in Test 5 near the water bottom with the use of Test 8 de-ghosting

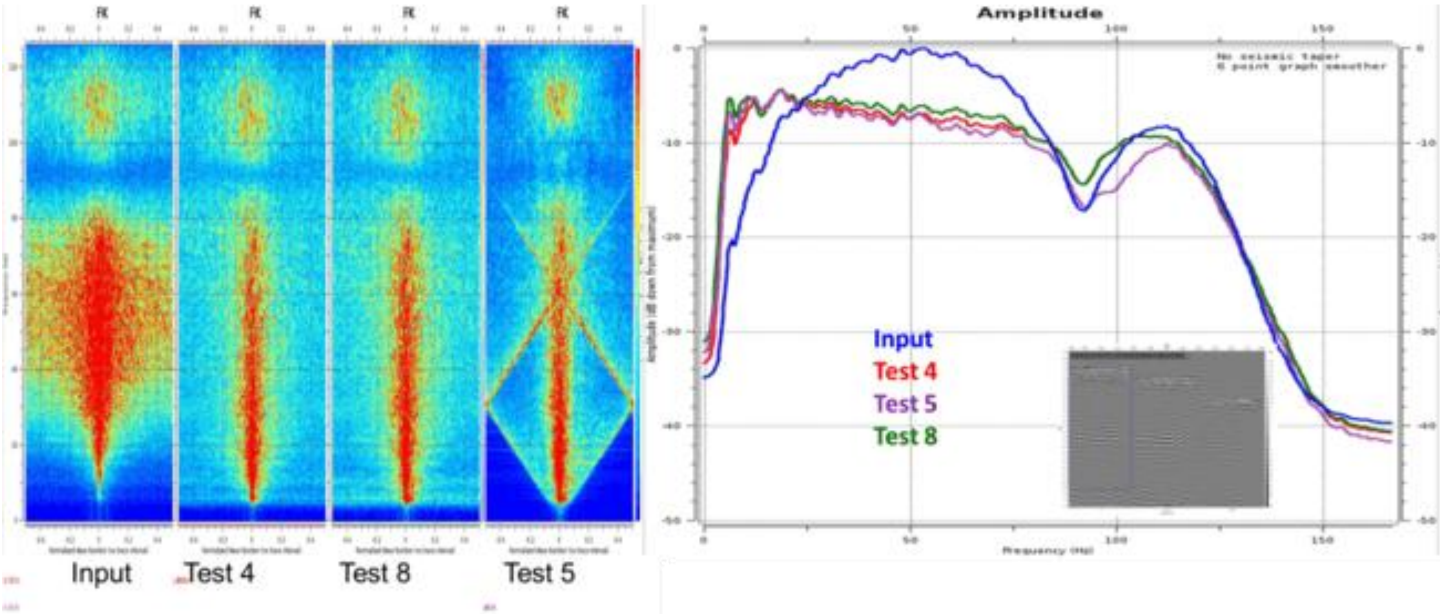

Figure 10: Near channel gather FK spectra show aliasing with RC increment in Test 5. This aliasing effect is not observed in Test 8 (variation of the RC)

Increasing low-frequency content from de-ghosting dominate the amplitude spectrum due to the absorption (Q) effect, the high frequencies are recovered with the application of Q compensation. Comparison of pre-migration stacks using a test Q of 35Hz at reference frequency of 100Hz and maximum gain of 3 showed that the resolution of the data using Test 8 appeared slightly better than using a constant high RC in Test 5 (Figure 10).

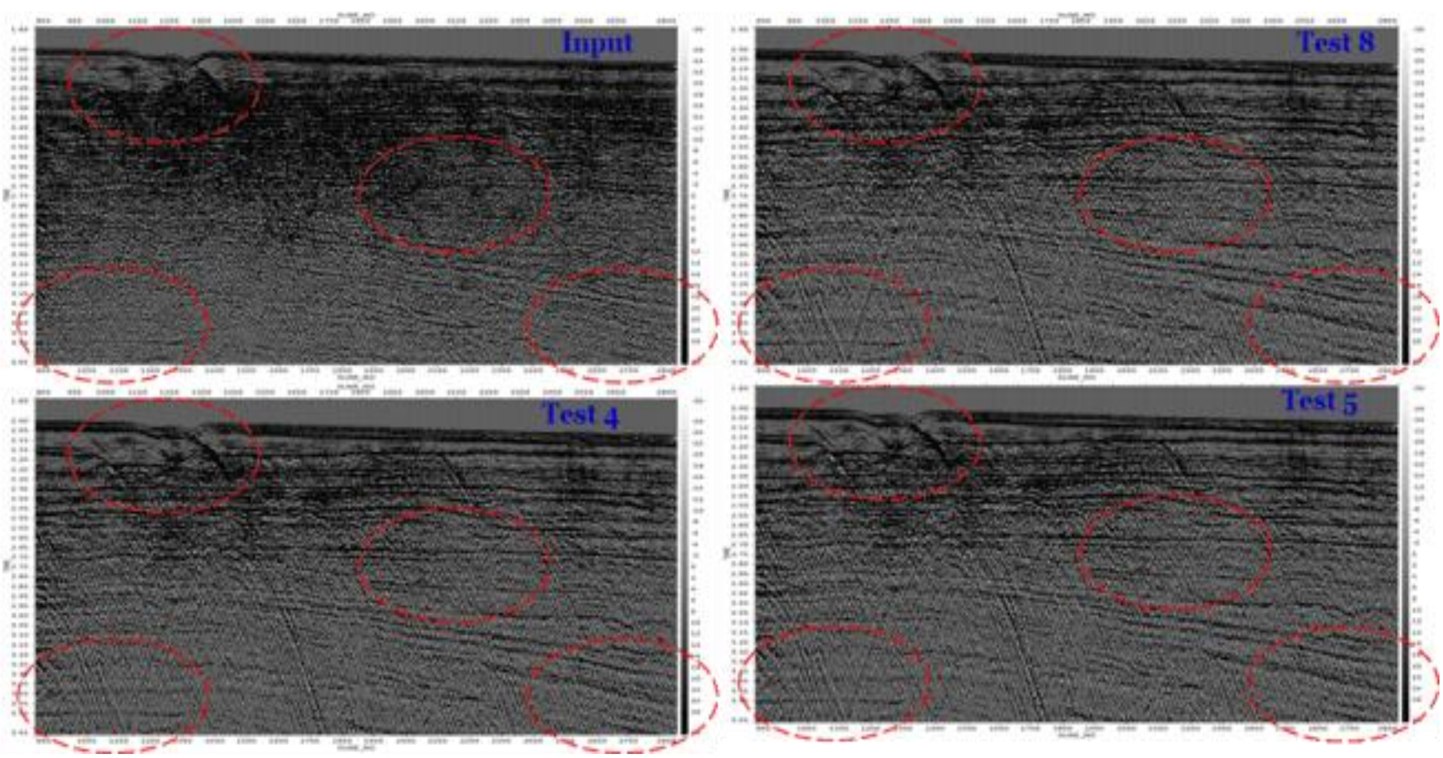

Figure 11: Pre-migration 3D Q-Stacks show some improved signal resolution of continuity and dips with the use of Test 8s

Final pre-migration 3D stacks result showed improvement of the data bandwidth with the application of de-ghosting to the conventional acquired data; with most improvement from the low to high frequency range observed with the use of Test 8.

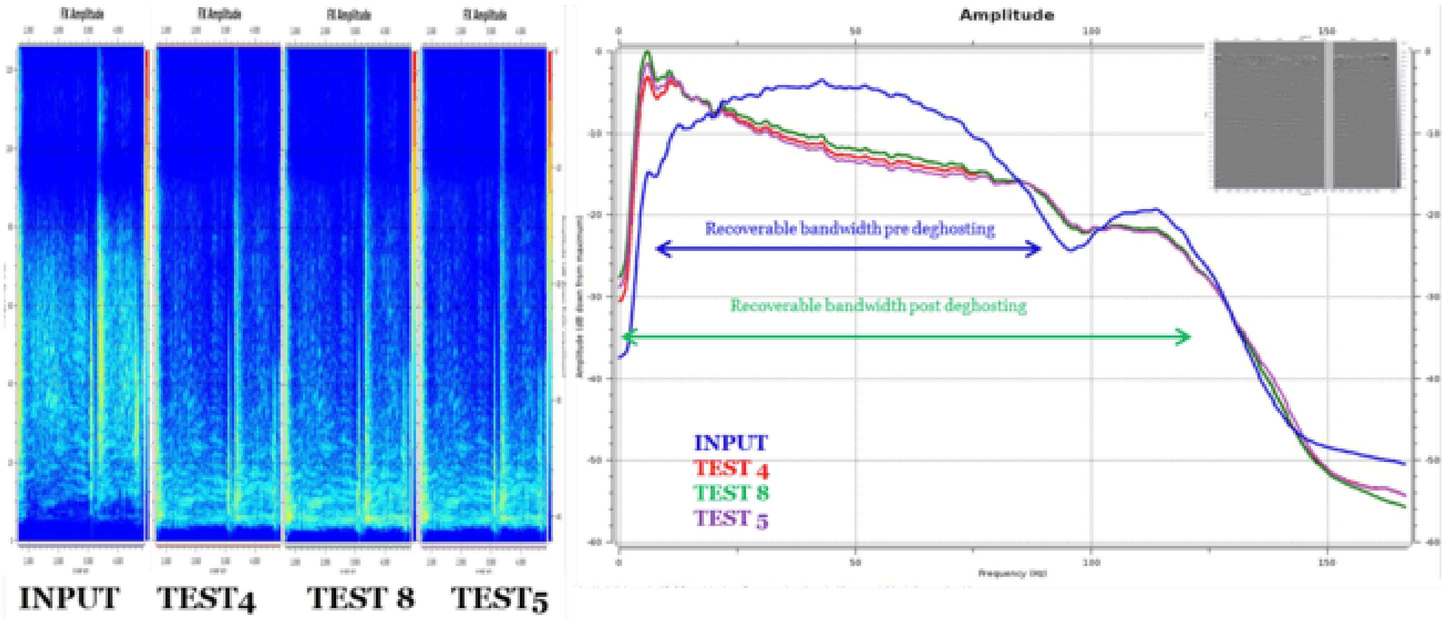

Figure 12: Pre-migration 3D stacks spectra FX and amplitude spectra without Q compensation show broadband enhancement of the data with de-ghosting

Conclusion

The significance of this study is to develop an improved methodology to improve the signal-to-noise ratio by optimizing the source and receiver ghost removal using frequency varying reflection coefficient. This can help improve the resolution of deeper reservoirs and shallow anomalies and reduce the turnaround time of either a fast-track processing or a full reprocessing project of a conventional streamer data.

Increasing the estimation of the RC during de-ghosting, appear to cause less optimal ghosts removal in the high frequency signals (and introduce artifacts) while enhancing the low frequency signals. By using varying RC at various frequency bands in a method not known from any past research reports., optimal ghost removal was achieved in the source and receiver side de-ghosting.

The bandwidth of the seismic data analysis is improved by applying source and receiver sides de-ghosting techniques. The linear curve of the amplitude spectrum post de-ghosting shows the expected natural decay caused by absorption (Q).

Acknowledgements

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References

Agnisola, P., O'Driscoll, R., Smith, P., Chu, D., Assiak, E., Ugwueze, C. and Ukerun P. (2019). The Effect of De-ghosting On the 4D Response: Usan Field, Nigeria. SEG Technical Program Expanded Abstract, pp 5214 - 5218. DOI: https://doi.org/ 10.1190/segam2019-3201739.1

Chigbo. J., Smith, M., Onojete, A., Ukerun, P., Mascomere, J., Ekut, E., Esotu, M. and Pou-Palome, S. (2021). Multi Azimuth Imaging of an Oil Bearing Faulted Sandstone Reservoir: A Nigeria Deep Offshore Case Study. 82nd EAGE Annual Conference and Exhibition. pp 1 – 5. DOI: https://doi.org/10.3997/2214-4609.202112756

Futterman, W. I. (1962). Dispersive Body Waves: Journal of Geophysical Research, Vol. 67, pp 5279 – 5291

O'Driscoll, R., King, D. and Tatarata A. (2013). Broad-Bandwidth Data Processing of Conventional Marine Streamer Data: An Offshore West Africa Field Case Study. SEG Houston Annual Meeting. pp 4231-4235 DOI: https://dx.doi.org/10.1190/segam2013-1019.1

Payne, N., Martin, T., Denly, J. and Afrazmanech, R. (2015). Multi Survey Matching of Marine Towed Streamer Data Using a Broadband Workflow: A Shallow Water Offshore Garbon Case Study. *SEG Technical Program Expanded Abstract,* 5132–5136. https://doi.org/10.1190/segam2015-5896165.1

Stolt. R. H. (1978). Migration By Fourier Transform. Geophysics. Vol. 43, pp 23 – 48

Yilmaz, O. (2001). Seismic Data Analysis: Processing, Inversion, And Interpretation of Seismic Data. Society of Exploration Geophysicists (Tulsa: USA)

Zhou, Z. Z., Cvetkovic, M., Xu, B. and Fontana, P. (2012). Analysis of A Broadband Processing Technology Applicable to Conventional Streamer Data: First Break. Vol. 30, pp 77 – 82.

Zhou, Z. J., Xu, B. and Naval, D. (2013). Broadband Processing of Conventional and Deep Tow Marine Streamer Seismic Data, ASEG Extended Abstracts. pp 1 – 4 DOI: https://doi.org/ 10.1071/ASEG2013ab383

Investment Strategies for Nigeria's Electricity Transmission Infrastructure by 2050

Chukwudi C. Okpalajiaku*
Energy Consultant
Abuja-FCT, Nigeria
chuxokpala@gmail.com

Anthony O. Ibe
University of Port Harcourt
Port Harcourt, Nigeria
anthony.ibe@uniport.edu.ng

Alwell Nteegah
University of Port Harcourt
Port Harcourt, Nigeria
alwell.nteegah@uniport.edu.ng

Abstract

The study analyses Nigeria's electricity infrastructure challenge through a Transmission Expansion Planning (TEP) study, using three scenarios NBS, BOT, and GDP to forecast population growth and electricity supply by 2050. The NBS scenario presents the most cost-effective option for Nigeria, requiring a US$18.9 trillion investment for tier 3 electricity access i.e., 80GW supply, while the GDP scenario has the least cost-effective of US$328.51 trillion for tier 5 electricity access i.e., 1.4TW supply by 2050. To achieve sustainable development, substantial investments in transmission infrastructure, public-private collaboration, and strong regulatory frameworks are recommended for Nigeria's energy future and economic prosperity by 2050.

Keywords: Investment Strategies, Nigeria's Electricity, Transmission Infrastructure.

1.0 Introduction

The Nigerian Electricity Supply Industry (NESI) has in the last few decades, struggled with persistent shortage in supply capacity, resulting in frequent power outages and load shedding to end-users. These challenges can be attributed to a combination of factors, including insufficient generation capacity, an inadequate and aging transmission infrastructure, disruptions in fuel supply and liquidity constraints as corroborated by several sources (Naibbi & Tukur, 2017; Osamonyi, Thomas, Akinrogunde, & Edwin, 2023; Magazzino, Drago, & Schneider, 2023). The outcome are that over 90 million Nigerians are living without access to electricity (Ubabudu & Raheem, 2023), while the rest of the population now settle for subpar, unpredictable, and unreliable electricity supply.

Access level for electricity in Nigeria, varies across different locations, with regional disparities and varying levels of development (NBS, 2020). The southern regions of Nigeria generally have higher levels of electricity access compared to the northern regions. According to (NBS, 2020), states in the northeast, such as Borno, Bauchi, Yobe, Adamawa, and Taraba, have particularly low levels of electricity access. According to reports from NERC, the average utilization rate of electricity in Nigeria from the third quarter of 2019 to the second quarter of 2020 was approximately 61%[1]. This implies that out of the available power generating capacity of around 5880.97 MW during the same period, only about 61% utilized, resulting in an average total generation during this time of about 3,600 MW.

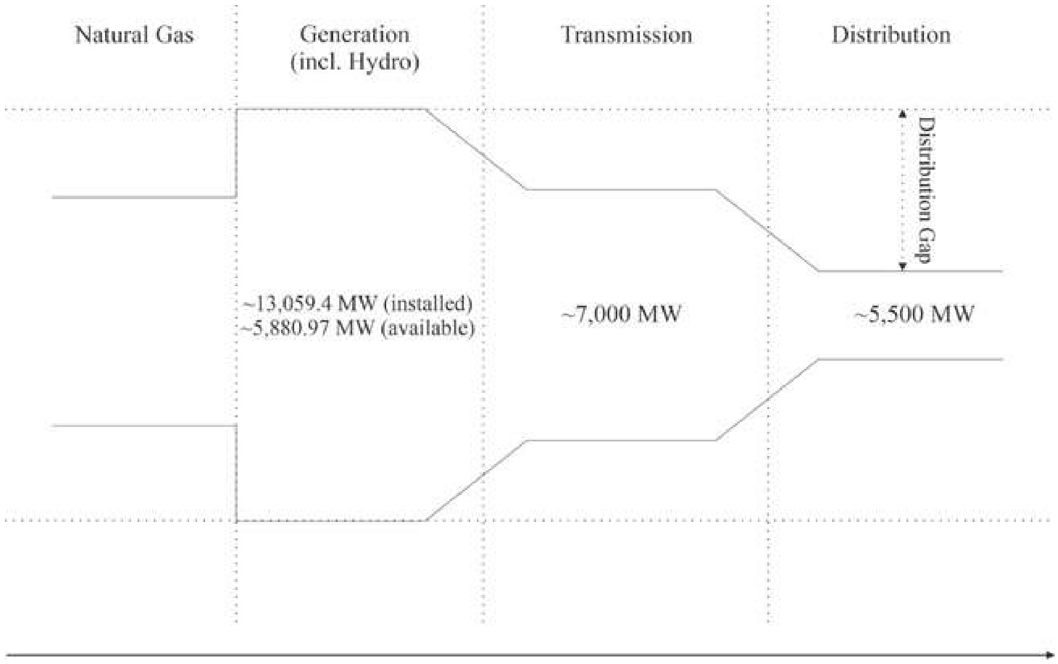
There are twenty-six (26) grid-connected generating plants with a combined installed capacity of 13,059.4 MW. However, the available capacity is only 45% of that, amounting to 5880.97 MW for over 200 million people i.e. approx. 53 kWh per capita to 55% of the population connected to the grid.

Similarly, the transmission network's theoretical capacity stands at 7,000 MW[2], but the available capacity is 5880.97 MW[3]. The theoretical capacity represents the maximum power the transmission network can handle under ideal conditions, considering the inventory of installed equipment on the network. Nonetheless, relying solely on theoretical assessments may not always provide a realistic and dependable estimate, as individual equipment efficiencies can vary. This evident difference between installed and available capacities points to an underlying issue within the NESI supply system. The transmission infrastructure in Nigeria is particularly afflicted by reliability problems, primarily attributed to the absence of redundancies and the network's radial nature[4].

The concentration of load demand in the South and South West regions where industrial and commercial business activities are most concentrated, coupled with the absence of generation stations in the central, North, and North Eastern regions, has led to a significant generation deficit across TCN planning regions. To address this issue and supply power to areas with little or no generation, long 330 kV and 132 kV transmission lines are constructed (radial system) to load centers. This radial nature of the national grid, by design, lacks detour routes or

[1] The Nigeria Electricity System Operator (nsong.org)
[2] Overview of the NESI: a presentation at the NERC Stakeholders' Workshop on the Electricity Act 2023
[3] Generation (nerc.gov.ng)
[4] Radial, Parallel, Ring main and Interconnected Distribution Systems | electricaleasy.com

alternative transmission paths. As a result, when accidents or equipment failures occur in the transmission system, there are no alternative routes to redirect power flow, leading to prolonged power outages and reduced system reliability. Consequently, there are significant power rationing measures in place, with average rationing periods ranging from 0 to 20 hours across the country (giz, 2015).



Source: NERC 2023 & Author's

Figure 1: Summary of NESI Bottlenecks[5]

Several studies corroborate the bottlenecks in the transmission lines that run across the country, passing through Lagos, the largest demand center (Onochie, Egware, & Eyakwanor, 2015; Ekong & Ekene, 2022). The transmission grid constraints in the Nigeria electricity supply industry (NESI) has so far limited electricity distribution in Nigeria to about 7,000 MW theoretically and 5,300 MW tested[6]. Despite several interventions and investments in transmission in recent years, Nigeria's power supply capacity remains overwhelmingly insufficient (Babatunde, et al., 2023), with severe economic implications for Nigeria, affecting businesses, industries, and daily livelihoods.

1.1 Power Supply Situation

1.1.1 Generation

The grid-connected generators in the NESI, *see* Table 1, largely comprised of 87% thermal and 13% hydroelectric generation mix[7]. Nigeria has notably struggled to convert its energy resources into electricity, and as a result, the country still relies heavily on thermal power plants to generate electricity. The electricity generation infrastructure in Nigeria is characterized by limited capacity, outdated equipment, and poor maintenance, which results in low levels of efficiency and frequent power outages (Ayamolowo, Buraimoh, Salau, & Dada, 2019). In

[5] Transmission Company of Nigeria (TCN)
[6] Transmission (nerc.gov.ng)
[7] Transmission Company of Nigeria (TCN)

addition, the power plants are often located far from major population centers, making it difficult to transmit electricity over long distances. In recent years, the government has made efforts to improve the state of electricity generation infrastructure in Nigeria through the development of new power generation projects and the rehabilitation of power plants[8].

Although the current national electrification rate hovers around 55.5%, with peak demand forecast approximately 14,630MW[9], power supply availability in both generation and transmission falls far short of sufficient levels. Table 1 and Figure 2 show the installed power generation and configuration respectively for Nigeria.

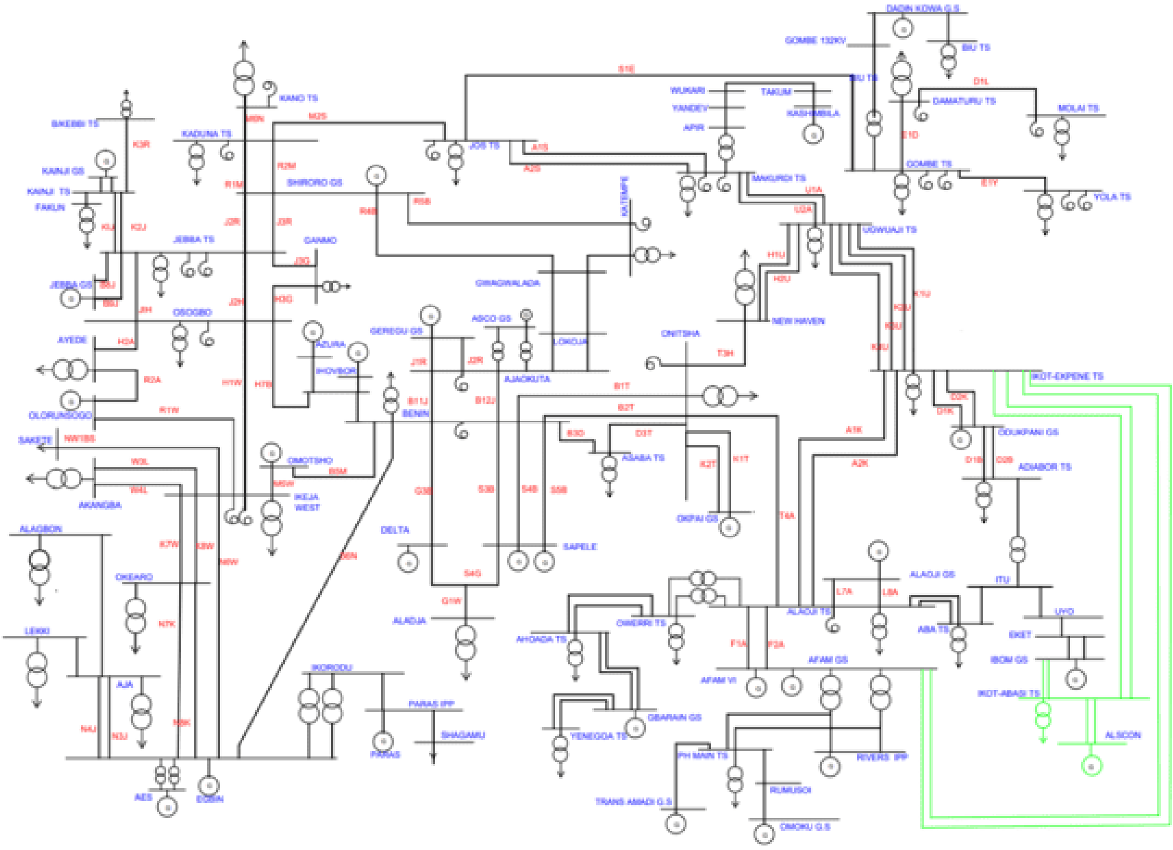
Table 1: Summary of Generation Capabilities in the NESI.

SNo	Plant	Installed Capacity (MW or x106)	Availability Factor (MW)	Average Availability (MW)
Privatised/Concessioned Companies – Hydro Stations				
1	Kainji G.S	760	0.5	380
2	Jebba G.S	578.4	0.67	387.528
3	Shiroro G.S	600	0.73	438
4	Dadin-Kowa	40	0	0
	Sub-Total	1978.4		1205.528
Privatised Companies – Thermal Stations				
5	Egbin G.S ST	1320	0.57	752.4
6	Sapele Steam	720	0.22	158.4
7	Delta II-IV G.S/Transcorp	900	0.45	405
8	Afam IV & V	351	0.22	77.22
9	Geregu G.S	435	0.86	374.1
10	Omotosho G.S	335	0.46	154.1
11	Olorunsogo	335	0.54	180.9
	Sub-Total	4396		2102.12
NIPP – Thermal Stations				
12	Sapele NIPP	500	0.18	90
13	Alaoji NIPP	500	0.32	160
14	Olorunsogo NIPP	750	0.04	30
15	Geregu NIPP	435	0.33	143.55
16	Omotosho NIPP	500	0.25	125
17	Ihovbor NIPP	500	0.12	60
18	Odukpani	625	0.71	443.75
19	Gbarain	120	0.2	24
	Sub-Total	3930		1076.3
IPP – Thermal Stations				
20	Okpai G.S	480	0.51	244.8
21	Afam VI G.S	650	0.59	383.5
22	ASCO	110	0	0
23	Ibom G.S	190	0.35	66.5
24	AES	294	0	0

[8] Generation - Niger Delta Power Holding Company (ndphc.net)
[9] TCN, "Transmission Expansion Plan, Development of Power System Master Plan for the Transmission Company of Nigeria," December 2017

25	Trans-Amadi	100	0.79	79
26	Rivers IPP	180	0.79	142.2
27	Azura IPP	461	0.92	424.12
28	Omoku G.S	150	0.59	88.5
29	PARAS Energy	95	0.72	68.4
30	TAOPEX Energy	45	0	0
	Sub-Total	2975		1497.02
	GRAND TOTAL .	13059.4		5880.968

Source: TCN, 2023



Source: TCN, 2022

Figure 2: Grid-Connected Generators on 330/132 kV Busses in the NESI[10]

1.1.2 Transmission

Transmission network in the NESI are composed of 330 kV and 132 kV transmission lines. The 330 kV lines make up the nationwide trunk system while the 132 kV lines make up the country's lower grid systems[11] of over 20,000 km transmission lines[12]. Figure 2 and Figure 3 respectively show the national transmission grid in Nigeria and a map of the national power transmission system with details on the transmission expansion plan. The primary power arteries are the transmission lines running from the Niger Delta in the south to the north via the largest demand center of Lagos. These transmission lines, however, currently face bottlenecks/constraints that prevent the full utilization of the generating capacity.

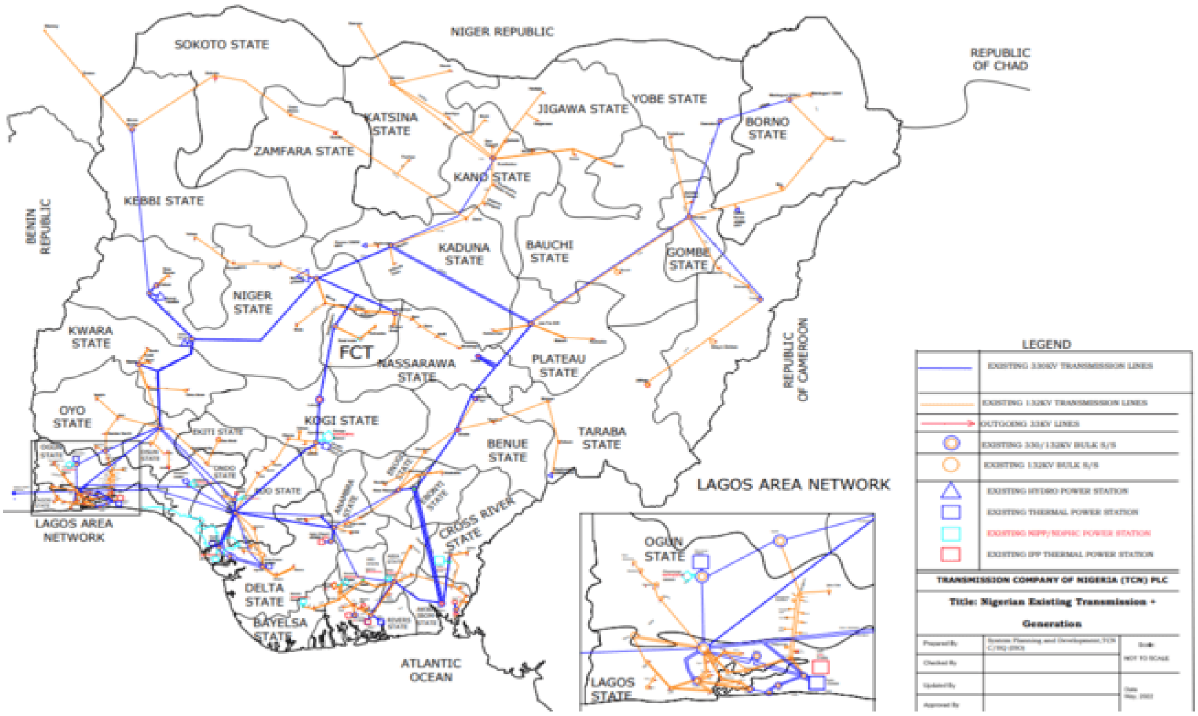
10 Transmission Company of Nigeria (tcn.org.ng)
11 Nigeria Electricity Sector - energypedia
12 Transmission (nerc.gov.ng)

The transmission network in the NESI grid is categorized into two main voltage levels:

1. 330 kV: These are high voltage networks that form a critical part of the national grid. They are responsible for transmitting bulk power over long distances from power generation stations to major load centres.
2. 132 kV: These busses are also considered high voltage networks and play a crucial role in further transmitting and distributing electricity from the 330 kV level to regional load centres, Distribution Companies (DisCos) and other consumers.

The use of two main voltage levels, 330 kV and 132 kV, indicates that the grid has been designed to handle both high and medium-voltage power transmission. High-voltage lines, operating at 330 kV, are typically utilized for long-distance transmission to minimize power losses during transportation over vast distances. These lines are suitable for transmitting power from major power plants or generation centres to substations or load centres located far away. On the other hand, medium-voltage lines, operating at 132 kV, are employed for shorter distance distribution to consumers. These lines are responsible for delivering electricity from power plants to DisCos before they are sent to residential, commercial, and industrial areas, ensuring that power reaches end-users efficiently and reliably, *see* Figure 4.

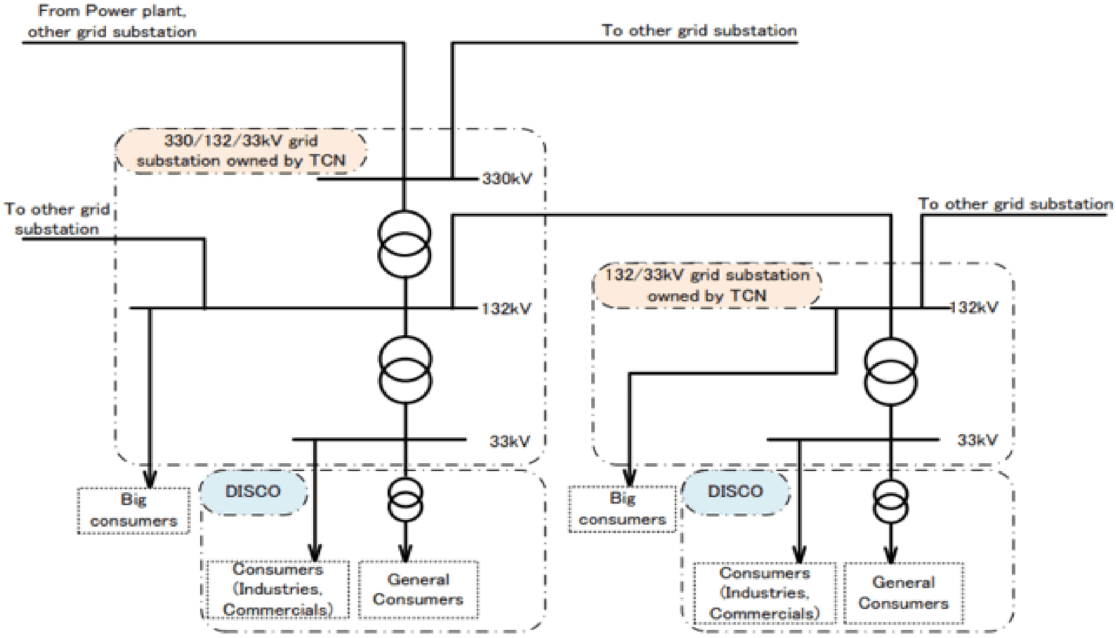
From Figure 2, grid-connected generating facilities are predominantly located in the southern parts of the country. This is likely due to the presence of natural gas resources in that region, explored for thermal power generation. On the other hand, the northern parts of the country have a smaller concentration of generation sources, which primarily consist of renewable energy sources such as hydroelectric systems. Additionally, there are a few off-grid solar and wind generation facilities in the north. The significant distance between the southern and northern regions of the country results in challenges related to power transmission. Specifically, when power is transmitted over long distances from the south to the north, there are extreme voltage drops that occur in the central and northern areas. These voltage drops lead to power losses and potential instability in the grid system.



Source: TCN, 2022

Figure 3: Map of Nigeria showing its Electricity Transmission Grid

Figure 3 and 4 present important information about the current condition of Nigeria's transmission grid network and shed light on the challenges it is encountering. Notably, the transmission network has experienced higher losses than the target allows in recent years. The Transmission Loss Factor (TLF) only witnessed a modest improvement of 0.81% between 2015 and 2022. Comparatively, Ghana has a significantly lower allowable TLF of 3.5%, whereas Nigeria's TCN is facing a higher TLF of 7.5%. These figures clearly indicate the difficulties and reliability concerns faced by Nigeria's transmission grid system. The higher transmission losses suggest inefficiencies and technical issues that need to be addressed urgently to enhance the overall reliability and efficiency of the transmission network.



Source: (JICA, 2020)

Figure 4: Structure of the NESI electricity supply system.

Figure 4 represents the NESI supply system, generation, transmission, and distribution segments in radial configuration, with transmission lines extending radially from main power stations and substations. The choice of a radial system in Nigeria is the result of historical development and ease of implementation. However, this radial configuration poses reliability challenges. In the event of equipment failures or outages, there are limited alternative routes (detour routes) available to redirect power flow. Consequently, the system is less reliable compared to other forms, leading to frequent power shortages and disruptions[13].

To ensure a robust and reliable power supply in Nigeria by 2050, substantial investments in upgrading existing transmission lines and constructing new corridors are essential. The national grid, with its 251-bus network, requires optimization to accommodate growing generating capacity, including both conventional and renewable sources. Balancing high and medium-voltage networks (330 kV/132 kV) will efficiently meet diverse regional demands. This investment is crucial for enhancing reliability and resilience, supporting economic growth, and integrating renewable energy for a sustainable future.

1.1.3 Distribution

There are eleven power Distribution Companies (DisCos) operating within the Nigerian Electricity Supply Industry (NESI). Each DisCo is assigned a specific franchise area where they are responsible for distributing electricity to residential, commercial, and industrial clusters within that region. The DisCos play a vital role in the NESI value chain, bridging the gap between bulk electricity generation by power Generation Companies (GenCos) and the final consumption by end-users. They act as intermediaries responsible for ensuring the efficient and reliable delivery of electricity to consumers.

[13] https://openjicareport.jica.go.jp/pdf/12339586_03.pdf

However, the performance of the DisCos has been a subject of concern in the NESI, with challenges such as revenue collection, metering gaps, and infrastructure deficiencies, i.e. Aggregated Technical Commercial and Collection (ATC&C) losses, including energy theft (Okafor, Madu, Ajaero, Agomuo, & Abu, 2020). To address these issues and improve the overall performance of the DisCos, various reforms and interventions have been proposed and implemented by the Nigerian government and regulatory authorities. A well-functioning and efficient distribution sector is crucial for achieving a stable and sustainable electricity supply system in the country.

Overall and across the entire value chain for electricity supply in Nigeria, the critical segment has been identified as the transmission segment, with bottlenecks to limit both generation and distribution alike.

1.2 Other studies

To ameliorate the situation, there have been a number of transmission expansion studies conducted in Nigeria in recent years. Some of the most notable include:

- The Nigeria Transmission Expansion Project Phase 1 (NTEP1)[14], funded by the African Development Bank (AfDB) to rehabilitate and expand the transmission network in Nigeria's North-West, South-East, and South-South regions of Nigeria. The project aims to increase the transmission capacity of the network by 1,400 megawatts (MW) and to improve the reliability of electricity supply to consumers in these regions by 2024.
- The Transmission Rehabilitation and Expansion Programme (TREP)[15], funded by the World Bank to rehabilitate and expand the transmission network in Nigeria's six geopolitical zones. The program aims to increase the transmission capacity of the network by 7,000 megawatts (MW) and to improve the reliability of electricity supply to consumers across the country by 2026.
- The National Integrated Power Projects (NIPP) Phase 2[16], funded by the Federal Government of Nigeria to construct new transmission lines and substations in Nigeria. The project aims to increase the transmission capacity of the network by 16,000 megawatts (MW) and to improve the reliability of electricity supply to consumers across the country by 2027.

These studies have identified several challenges that need to be addressed in order to expand the transmission network in Nigeria including the lack of funding, land acquisition problems, environmental concerns and delays in project implementation. Despite these challenges, there is a growing consensus that transmission expansion is essential for improving the reliability and quality of electricity supply in Nigeria. The studies that have been conducted have provided valuable insights into the challenges and opportunities associated with transmission expansion in Nigeria. These insights will be essential for developing and implementing effective transmission expansion strategies in the years to come.

In addition to the studies mentioned above, there have also been a number of other studies conducted on transmission expansion in Nigeria (Fichtner, 2017; JICA, 2020). These studies

[14] Nigeria - Nigeria Transmission Expansion Project Phase 1 (Ntep1) - Project Appraisal Report | African Development Bank Group - Making a Difference (afdb.org)
[15] TREP 2 (tcn.org.ng)
[16] NIPP Phase II - Niger Delta Power Holding Company (ndphc.net)

have focused on a variety of topics, including the impact of transmission expansion on economic growth, the role of transmission expansion in achieving universal access to electricity and best practices for implementing transmission expansion projects However, the studies conducted so far have mostly focused on specific sections or regions of Nigeria where grid-level electricity may be economical, rather than the entire country.

Given the projected increase in population and energy demand, it becomes essential to formulate comprehensive strategies to accommodate this growth and prepare for the required but missing investments. As the former TCN MD rightly puts it *"Lack of investment, managerial capacity crippling Nigerian power sector"*[17]. With the necessary investment strategy, Nigeria should be able to realise its economic potential and improve livelihoods. Hence the need for a comprehensive Transmission Expansion Planning (TEP) study and development of investment strategies, to allow for different electricity access scenarios as provided by the Multi-Tier Framework (MTF) for electricity access, developed by the Sector Management Assistance Program (ESMAP) unit of the World Bank.

2.0 Materials and Methods

The study utilized a descriptive design to analyze Nigeria's electricity challenges, focusing on insufficient supply capacity, transmission disruptions, and disparities in access. It aimed to propose strategies for optimizing and expanding the transmission system to meet growing demand by 2050. Data were gathered from various sources, primarily focusing on transmission-related data across Nigeria.

Using the General Algebraic Modelling System (GAMS), the study forecasted electricity supply and population trends up to 2050, optimizing the national transmission grid accordingly. Three scenarios were developed based on historical data, offering insights into potential trajectories for electricity supply and demand.

To model electricity demand and supply scenarios, the study employed the Multi-Tier Framework (MTF) for Electricity Access, ensuring alignment with international standards. An assessment of the transmission infrastructure was conducted to identify areas requiring reinforcement.

Investment requirements for each scenario were computed to achieve specific access tiers by 2050. Policy recommendations were proposed to enhance Nigeria's transmission network, ensuring its readiness for future challenges.

2.1 Scenario Definition

The study adopted three population growth scenarios for Nigeria up to 2050, presented in Figure 5. Using GAMS software, the Ord operator was utilized to forecast the country's population from the last recorded population census in 2006 to 2050 under the NBS, BOT, and GDP scenarios. By considering these scenarios and applying historical growth rates, the study projected the potential future population of Nigeria, essential for energy demand planning and transmission expansion strategies.

[17] Lack of investment, managerial capacity crippling Nigerian power sector - Former TCN MD - Daily Post Nigeria

The adoption of the three population growth scenarios (NBS, BOT, and GDP) in the study was informed by previous studies conducted by (Onwuka, 2018; Onyeije, 2019) These studies investigated historical population data and trends to derive the growth rates associated with each scenario. By selecting these scenarios, the study aimed to encompass various potential trajectories of population growth in Nigeria up to 2050. Considering different scenarios helps account for uncertainties and allows for a more comprehensive evaluation of transmission expansion strategies that can cater to varying population dynamics in the future.

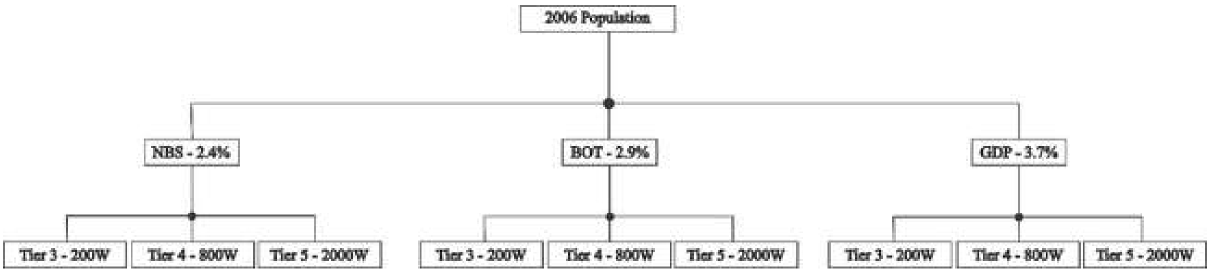


Figure 5: Summary of Scenario Definition

The study recognizes the impact of population growth on electricity demand in Nigeria. By projecting future population scenarios using NBS, BOT, and GDP models, it estimates increased electricity demand. Analyzing this alongside supply requirements identifies challenges and opportunities for meeting energy needs, guiding transmission infrastructure expansion to accommodate rising demand.

2.2 Demand and Supply Forecast

The scenarios for population forecast flow directly into the top three select tiers for electricity access in the MTF as set out by ESMAP (Bhatia & Angelou, 2015), *see* Table 2. Each of these tiers is considered for the three scenarios of population growth, resulting in a total of nine electricity demand and supply scenarios. By aligning population scenarios with electricity access tiers, the study incorporates a more comprehensive understanding of access disparities and identifies specific areas that require attention and investment. This approach allows for a nuanced assessment of electricity access and enables the identification of strategies to address gaps and improve electricity access across different possible scenarios.

Table 2: Multi-Tier Framework (MTF) for Electricity Access by ESMAP

			Tier 0	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
ATTRIBUTES	Capacity	Power		Very Low Power. Min 3W	Low Power. Min 50 W	Medium Power. Min 200W	High Power. Min 800W	Very high power. Min 2000 W
		AND Daily Capacity		Min 12 Wh	Min 200 Whr	Min 1.0 kWh	Min 3.4 kWh	Min 8.2 kWh

OR Services	Lightening of 1,000 lmhrs per day and phone charging	Electrical Lighting, air circulation, television, and phone charging are possible.	

Source: (Bhatia & Angelou, 2015)

The study bases its electricity demand scenarios on the Energy Sector Management Assistance Program's (ESMAP) Multi-Tier Framework (MTF), which outlines electricity access requirements across tiers 3, 4, and 5. These tiers represent increasing levels of electricity access, measured by per capita consumption. By integrating the MTF, the study ensures a standardized approach to assess electricity access, accommodating diverse needs and demands.

Moreover, the MTF aids in monitoring progress over time, enabling policymakers to evaluate interventions aimed at improving electricity access effectively. Integrating population forecasts with the MTF allows the study to project the required investment in electricity infrastructure to meet rising demand as Nigeria's population grows. This approach helps assess the implications of different population growth rates on electricity demand and supply, guiding strategic investment decisions.

2.3 NESI Transmission Infrastructure and Expansion Modeling

The study conducted modelling and analysis of Nigeria's transmission infrastructure to assess its capacity and performance under varying population growth and energy supply scenarios. Data on the transmission grid's configuration, including generation sources, transmission lines, and cost parameters, was gathered from sources like the Transmission Company of Nigeria (TCN). The cost information is summarized in Table 3, providing an overview of the national grid's cost parameters for materials.

Using General Algebraic Modelling System (GAMS), the study simulated the behaviour of the transmission network across a 251-bus network to analyse its performance and limitations under different scenarios. This analysis aimed to understand how well the current transmission grid could accommodate increased power flow resulting from population growth and changes in energy supply by 2050 and beyond, offering valuable insights for future infrastructure planning and development.

Table 3: Cost Components Considered in the Cost Estimation

Unit Cost	
Transmission Lines	
	[Million US$/km]
132 kV DC Line	0.26
330 kV DC Line	0.45

500 kV SC Line	0.28
750 kV SC Line	0.35
Substations	
	Cost per HV feeder
	[Million US$]
132 kV HV equipment	0.70
330 kV HV equipment	1.00
500 kV HV equipment	1.30
750 kV HV equipment	2.20
60 MVA Transformer 132/33 kV	0.80
150 MVA Transformer 330/132 kV	1.50
1000 MVA Transformer 750/330 kV	10.0
33 kV Switchgear	0.70
Civil Works, Steel, Protection, Station Control, Auxiliary Power Supply, Installation, etc.	0.90

Source: TCN, 2023

The study's modeling approach for assessing and expanding Nigeria's transmission infrastructure aligns with established practices detailed in (Soroudi, 2017). Using transmission bus data from TCN, a comprehensive model of the current transmission system was conducted in GAMS. By considering nine (9) electricity supply scenarios and projecting demand up to 2050, alongside investment and operational costs, the study aimed to enhance Nigeria's transmission infrastructure, providing accurate insights for future expansion plans.

$$OF = T \times OpC + InvC \tag{1.1}$$

Where:

$$OpC = \sum_{g \epsilon \Omega_G} b_g P_g + \text{VOLL} \sum_i LS_i \tag{1.2}$$

$$InvC = \left(-\eta_{ij}^0 + \sum_{k.ij} \propto_{ij}^k\right) C_{ij} \tag{1.3}$$

$$P_{ij}^k - B_{ij}\left(\delta_i - \delta_j\right) \leq \left(1 - \alpha_{ij}^k\right) M \tag{1.4}$$

$$P_{ij}^k - B_{ij}\left(\delta_i - \delta_j\right) \geq -\left(1 - \alpha_{ij}^k\right) M \tag{1.5}$$

$$\sum_{g \epsilon \Omega_G^i} P_g + LS_i - L_i = \sum_{j \in \Omega_\ell^i} P_{ij} : \lambda_i \quad i \in \Omega_B \tag{1.6}$$

$$-P_{ij}^{max} \alpha_{ij}^k \leq P_{ij}^k \leq P_{ij}^{max} \alpha_{ij}^k ij \in \Omega_\ell \tag{1.7}$$

$$P_g^{min} \leq P_g \leq P_g^{max} \tag{1.8}$$

$$if\ \eta_{ij}^0 = 1\ then\ \alpha_{ij}^{k=1} = 1 \tag{1.9}$$

$$B_{ij} = \frac{1}{x_{ij}} \tag{1.10}$$

$$\alpha_{ij}^{k} \in \{0, 1\} \tag{1.11}$$

$$k \in \{1, 2, 3, 4\} \tag{1.12}$$

The study's methodology for conducting the Transmission Expansion Plan (TEP) analysis involves a comprehensive modeling approach, as described by the equations 1.1 to 1.12. The objective function, represented by equation (1.1), considers both operational costs and investment costs for the transmission expansion. Operational costs are calculated using equation (1.2), while investment costs are determined using models presented in equations (1.3), (1.4), and (1.5). The parameter "M" or big M, introduced in equations (1.4) and (1.5), plays a role in formulating constraints or binary variables to represent investment decisions as coined in (Bussieck & Pruessner, 2003).

To ensure power balance between generated power, load shedding, demand, and line flows, equation (1.6) is introduced to represent power flow constraints. Equation (1.7) models limitations on line flows, and the impacts of line investment decisions, α_{ij}^{k}, are formulated. Generation operating limits are defined in equation (1.8), while the initial status of each line is described in equation (1.9).

The transmission network used for the analysis is represented in Figure 2, and detailed data for transmission expansion planning is provided in Table 3 and bus data by TCN. The investment costs, denoted as C_{ij}, are given in million dollars, and the Value of Lost Load (VOLL) is assumed to be 1000 \$/MWh.

3.0 Results and Discussion

The outcome of the Transmission Expansion Planning (TEP) study conducted in Nigeria provides valuable insights into the country's electricity infrastructure and the necessary upgrades by 2050. The TEP studies have identified optimal solutions for reinforcing and reconductoring existing transmission lines, as well as expanding the transmission infrastructure to reach unelectrified communities. The findings are detailed in Table 4, which presents the investment costs for different tiers of electricity consumption per capita under the NBS, BOT, and GDP scenarios for the year 2050.

3.1 NBS Scenario: Under the NBS scenario, Nigeria's population is projected to reach 398.63 million by 2050, with a growth rate of 2.40% per year. This scenario anticipates three tiers of electricity consumption per capita. At Tier 3, with 200 Watt per Head, the energy demand is estimated to be 80 GW, requiring a total investment cost of \$18.900 trillion for transmission expansion. Tier 4, with 800 Watt per Head, sees an energy demand of 319 GW, with an associated transmission expansion cost of \$75.429 trillion. Lastly, Tier 5, at 2000 Watt per Head, has a significant energy demand of 797 GW, with transmission expansion estimated at \$188.48 trillion, representing advanced urban areas and regions with high energy-intensive activities.

3.2 BOT Scenario: In the BOT scenario, Nigeria's population is forecasted to reach approximately 493.91 million by 2050, with a growth rate of 2.90% per year. Similar to the NBS scenario, three tiers of electricity consumption per capita are considered. Tier 3, with 200 Watt per Head, estimates an energy demand of 99 GW, requiring an investment of \$23.394 trillion for transmission expansion. Tier 4, with 800 Watt per Head, projects a demand of 395 GW, with transmission expansion costs totalling \$93.404 trillion. Lastly, Tier 5, at 2000 Watt per Head, forecasts an energy demand of 988 GW, necessitating $233.66 trillion for transmission expansion, representing advanced urban and industrial areas.

3.3 GDP Scenario: Under the GDP scenario, Nigeria's population is projected to be approximately 694.44 million by 2050, with a growth rate of 3.70% per year. This scenario also considers three tiers of electricity consumption per capita. Tier 3, with 200 Watt per Head, estimates an energy demand of 139 GW, requiring an investment of $32.855 trillion for transmission expansion. Tier 4, at 800 Watt per Head, forecasts a demand of 556 GW, with transmission expansion costs totalling $131.48 trillion. Lastly, Tier 5, with 2000 Watt per Head, projects an energy demand of 1389 GW, necessitating $328.51 trillion for transmission expansion, representing advanced urban and industrial areas.

Table 4: Summary of Transmission Investment Strategies in the NESI by 2050.

Scenario	Growth Rate	Population by 2050 (millions)	Tier	Watt (W) per Capita	Energy Supply by 2050 (GW)	Total Investment Cost (US $ trillion)
NBS	2.40%	398.63	3	200	80	18.900
			4	800	319	75.429
			5	2000	797	188.48
BOT	2.90%	493.91	3	200	99	23.394
			4	800	395	93.404
			5	2000	988	233.66
GDP	3.70%	694.44	3	200	139	32.855
			4	800	556	131.48
			5	2000	1389	328.51

These investment strategies provide valuable insights into the potential future needs of Nigeria's electricity transmission infrastructure. They consider different growth rates, population projections, and energy demand estimates to develop investment plans that can accommodate the nation's increasing energy requirements. The scenarios highlight the importance of proactive planning and targeted investments to support sustainable development and ensure the reliable supply of electricity to meet the needs of a growing population and expanding economy. Policymakers, regulators, and industry stakeholders can use this information to make informed decisions and allocate resources effectively to achieve a robust and resilient electricity transmission system in Nigeria by 2050.

4.0 Conclusion

This study on electricity transmission expansion for Nigeria by 2050 has provided valuable insights into the nation's future power transmission planning. By considering critical factors such as population growth and projected electricity demand and supply, various scenarios have been evaluated to identify the most promising option for Nigeria's energy future. Among the studied scenarios, the NBS scenario with a 2.4% population growth rate stands out as the most favorable choice, exhibiting notable improvements in electricity consumption per capita and requiring a cost-effective investment of US$18.9 trillion to achieve tier 3 electricity access of 200W per capita. On the other hand, the GDP scenario, with its best electricity consumption outlook, presents the highest investment cost at US$328.51 trillion.

The TEP study highlights the need for substantial investments in Nigeria's electricity transmission infrastructure to address the challenges of population growth and increasing energy demand. Expanding and modernizing the transmission network is vital to ensure a reliable and efficient supply of electricity across different regions and consumption tiers, fostering economic growth and development. By adopting a cohesive approach involving collaboration between the public and private sectors, strong regulatory frameworks, and transparent contract agreements, Nigeria can successfully implement these scenarios and achieve sustainable development in the electricity supply industry, ultimately paving the way for a more sustainable energy future, ensuring economic prosperity for its citizens by 2050.

4.1 Policy Recommendations

Based on the outcome of the Study, the following policy recommendations are proposed to guide Nigeria's energy planning and investment decisions:

1. Energy Efficiency Programs: Establish initiatives to reduce electricity consumption and optimize energy use.
2. Flexible Transmission Planning: Develop adaptable frameworks to enhance transmission stability and reliability.
3. Public-Private Partnerships (PPPs): Encourage collaboration between public and private sectors to expedite infrastructure projects.
4. Long-Term Investment Strategy: Align investment decisions with future energy needs and technological advancements.
5. Capacity Building and Local Expertise: Invest in skills development to optimize project execution and maintenance.
6. International Cooperation: Engage with global partners to access knowledge, technology, and funding for sustainable energy projects.

By implementing these recommendations, Nigeria can make informed decisions in transmission expansion planning, leading to a resilient and efficient power transmission system, thereby bolstering energy security and economic prosperity.

Nomenclature

Indices and Sets

g	Index of thermal generating units
i, j	Index of network buses

Ω_G	Set of all thermal generating units
Ω_G^i	Set of all buses connected to bus i
Ω_ℓ^i	Set of all buses connected to bus i
Ω_B	Set of network buses

Parameters

M	Big number
T	Duration of planning period (h)
L_i	Electric power demand in bus i at time t
b_g	Fuel cost coefficient of thermal unit g
η_{ij}^0	Initial status of branch connecting bus i to j
C_{ij}	Investment cost for branch connecting bus i to j
γ_{ij}	Investment cost of phase shifter in line ij
$P_g^{max/min}$	Maximum/minimum limits of power generation of thermal unit g
P_{ij}^{max}	Maximum power flow limits of branch connecting bus i to j
ψ_{ij}^{max}	Maximum phase shift in line connecting bus i to bus j
x_{ij}	Reactance of branch connecting bus i to j
B_{ij}	Susceptance of branch connecting bus i to j
$VOLL$	Value of loss of load ($/MW h)

Variables

P_{ij}^k	Active power flow of branch k connecting bus i to j (MW)
P_g	Active power generated by thermal unit g (MW)
α_{ij}^k	Binary variable to model the investment decision regarding the line k at the right of way ij
I_{ij}^k	Binary variable to model the investment decision regarding the phase shifter in line k at the right way ij
λ_i	Locational marginal price in bus i ($/MW h)

LS_i	Load shedding in bus i (MW)
ψ_{ij}	Phase shift in line connecting bus
OPC	Total operating costs ($)
OF	Total costs ($)
$INVC$	Total investment costs ($)
δ_i	Voltage angle of bus i (rad)

Acronyms

TCN	Transmission Company of Nigeria
NERC	Nigeria Electricity Regulation Commission
NBS	National Bureau of Statistics
BOT	Balance of Trade
GDP	Gross Domestic Product
MTF	Multi-Tier Framework
NESI	Nigerian Electricity Supply Industry
GAMS	General Algebraic Modeling System

References

Ayamolowo, O. J., Buraimoh, E., Salau, A. O., & Dada, J. O. (2019). Nigeria Electricity Power Supply System: The Past, Present and the Future. *2019 IEEE PES/IAS PowerAfrica.* 2019 IEEE PES/IAS PowerAfrica. doi:https://doi.org/10.1109/PowerAfrica.2019.8928767

Babatunde, O., Buraimoh, E., Tinuoye, O., Ayegbusi, C., Davidson, I., & Ighravwe, D. E. (2023, December 07). Electricity sector assessment in Nigeria: the post-liberation era. *Taylor & Francis Online*, 1-24. doi:https://doi.org/10.1080/23311916.2022.2157536

Bhatia, M., & Angelou, N. (2015). *Beyond Connections: Energy Access Redefined.* Sustainable Energy For All, Energy Sector Management Assistance Program (ESMAP). Washington DC: The International bank for Reconstruction and Development/The World Bank Group. Retrieved April 16, 2023, from https://documents1.worldbank.org/curated/en/650971468180259602/pdf/105054-ESM-P148200-ADD-SERIES-PUBLIC-FINAL-ESMAP-Beyond-Connections-TR008-15-optimized.pdf

Bussieck, M. R., & Pruessner, A. (2003, April). Mixed-Integer Nonlinear Programming. *SIAG/OPT Views-and-News, 14*(1), 19-22. Retrieved May 3, 2023, from https://optimization-online.org/wp-content/uploads/2003/05/651.pdf

Ekong, C., & Ekene, O. E. (2022, June). Evaluating Electricity Power Transmission Challenges In Nigeria: An Analytical Hierarchy Process Approach. *International Journal of Innovative Research and Advanced Studies, 9*(6). Retrieved July 21, 2023, from https://www.ijiras.com/2022/Vol_9-Issue_6/paper_7.pdf

Fichtner. (2017). *Transmission Expansion Plan: Development of Power System Master Plan for the Transmission COmpany of Nigeria.* Nigeria Electricity and Gas Improvement Project. Stutgard: Fichtner. Retrieved July 21, 2023

giz. (2015). *The Nigerian Energy Sector: An Overview with Special Emphasis on Renewable Energy, Energy Efficiency and Rural Electrification.* Abuja: Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. Retrieved May 24, 2023, from https://www.giz.de/en/downloads/giz2015-en-nigerian-energy-sector.pdf

JICA. (2020). *Preparatory Survey for Power transmission Project in the Federal Republic of Nigeria.* Feasibility Final Report, Japan Internatiuonal Cooperation Agency (JICA), Abuja. Retrieved July 15, 2023, from https://openjicareport.jica.go.jp/pdf/12362752_01.pdf

Magazzino, C., Drago, C., & Schneider, N. (2023, June). Evidence of supply security and sustainability challenges in Nigeria's power sector. *Utilities Policy, 82*. doi:https://doi.org/10.1016/j.jup.2023.101576

Naibbi, A. I., & Tukur, Y. M. (2017, January 02). Ensuring Optimal Electricity Generation and Supply: The Paradox of Nigeria's Situation. *International Research Journal of Environmental Sciences and Studies, 2*(1), 1-14. Retrieved July 21, 2023, from https://d1wqtxts1xzle7.cloudfront.net/52343113/Ensuring_Optimal_Electricity_Generation-libre.pdf?1490706114=&response-content-disposition=inline%3B+filename%3DEnsuring_Optimal_Electricity_Generation.pdf&Expires=1689906420&Signature=AB-gQF~g0IWz2NO5BuvyMmF

NBS. (2020). *Nigeria Living Standards Survey 2020.* Survey, National Bureau of Statistics, FCT. doi:https://nigerianstat.gov.ng/elibrary/read/1123

Okafor, C. C., Madu, C. N., Ajaero, C. C., Agomuo, K., & Abu, E. (2020, September). Towards Sustainable Power Supply and Consumption of an Emerging Economy (Nigeria). *Journal of Economic Development, Environment and People*(4), 6-22. Retrieved July 21, 2023, from https://www.ceeol.com/search/article-detail?id=939565

Onochie, U., Egware, H., & Eyakwanor, T. (2015, April). The Nigeria Electric Power Sector (Opportunities and Challenges). *Journal of Multidisciplinary Engineering Science and Technology, 2*(4). Retrieved July 21, 2023, from https://www.jmest.org/wp-content/uploads/JMESTN42350093.pdf

Onwuka, E. (2018). *Integrated Modeling Framework for Gast-to-Power Systems Analysis.* PhD Thesis, University of Port Harcourt. Retrieved June 16, 2023

Onyeije, I. J. (2019). *Modeling Sustainable Electricity Supply for Nigeria.* University of Port Harcourt, Emerald Energy Institute. Port Harcourt: Emerald Energy Institute. Retrieved June 06, 2023

Osamonyi, O., Thomas, T. G., Akinrogunde, O. O., & Edwin, T. E. (2023, March). Powering the Future: A Sustainable Reform Plan for Overcoming Transmission and Distribution Challenges in Nigeria Power Sector. *African Scholar Journal of African Innovation & Advanced Studies (JAIAS-2), 28*(2), 121-146. Retrieved July 21, 2023, from https://www.africanscholarpublications.com/wp-content/uploads/2023/04/AJAIAS_VOL28_NO2_MAR-2023-9.pdf

Soroudi, A. (2017). *Power System Optimization Modeling in GAMS* (1 ed.). Ireland: Springer Cham. doi:https://doi.org/10.1007/978-3-319-62350-4

Ubabudu, M. C., & Raheem, B. A. (2023). Nigeria's Population Politics and Its Janus-Headed Implications: A Critical Analysis. *International Journal of Business and Management Review, 11*(5), 39-56. Retrieved July 21, 2023, from https://tudr.org/id/eprint/1851/

Accelerated projection and contraction method for solving quasi-monotone variational inequalities in Hilbert spaces

Nwawuru F.O[1*], Ezeora J.N[2] and Igbokwe D.I[3]

[1,] Department of Mathematics, Faculty of Physical Sciences Chukwuemeka Odumegwu Ojukwu University, Uli Campus Anambra State, Nigeria.*
[*]Corresponding author's email: fo.nwawuru@coou.edu.ng
[2] Department of Mathematics/Statistics, Faculty of Science University of Port Harcourt, Rivers State, Nigeria. Email: jeremiah.ezeora@uniport.edu.ng
[3] Department of Mathematics/Statistics, Faculty of Science, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria. Email: igbokwedi@yahoo.com

Abstract
Motivated and inspired by a novel article of Tan and Li (2022) on projection and contraction method for solving variational inequalities, this study examined an improved and generalized version of their work. To be precise, we provide an iterative algorithm for solving variational inequalities with quasi-monotone and Lipschitz continuous operator in real Hilbert spaces. A self-adaptive stepsize is incorporated and our computation does not involve the prior information of the Lipschitz constant of the nonlinear operator. More so, a weaker assumption than sequentially weakly continuity condition is considered. A strong convergence of the proposed algorithm is established under some mild assumptions. Furthermore, some numerical examples are equally provided.

Keywords. Projection and Contraction Method; Pseudomonotone, Quasimonotone.

Mathematics Subject Classification: 47H05; 47H09; 47H25; 49J40

1. Introduction

The purpose in this research paper is to improve on the recent work of Tan and Li (2022) and highlight some achievements in this research direction. The classical variational inequality problem (VIP) of Fichera (1963; 1964) for $\mathcal{A}$ on C has the following structure:

$$\text{Find a point } x^* \in C \text{ such that } \langle \mathcal{A}x^*, x - x^* \rangle \geq 0, \forall\, x \in C \tag{1.1}$$

The solution set of problem (1.1) (VIP) is denoted by $VIP(C, A)$. The first problem involving variational inequality was first developed to solve equilibrium problems. To be concise, the Signorini problem (1959) was solved in the year 1963, by Fichera (1964). The existence of solutions of VIP was further established by Hartman and Stampacchia (1966; 1967). Variational inequality has been found to have numerous applications in many areas of mathematics, such as in partial differential equations, optimal control, optimization, mathematical programming and some other nonlinear problems (Censor et al., 2011; Chidume and Nnakwe, 2019; Chidume et al., 2016; Ezeora and Nnakwe, 2021).

Many methods have been developed in the literature for solving (1.1). However, there are two prominent methods: the regularized and projection method. The focus in this paper is on the projection method. It is known that finding the solution of VIP is equivalent to approximating the solution of fixed point problem (FPP):

$$find\ x^* \in C\ such\ that\ x^* = P_C(x^* - \lambda \mathcal{A} x^*), \tag{1.2}$$

where λ is a positive real number and $P_C: C \to \mathcal{H}$ is the metric projection. Therefore, the iterative sequence $\{x_n\}$ is generated via the following formula:

$$x_{n+1} = P_C(I - \lambda \mathcal{A})x_n, \tag{1.3}$$

where the operator $\mathcal{A}: \mathcal{H} \to \mathcal{H}$ is an α −inverse strongly monotone ($\alpha - ism$), L −Lipschitz continuous and $\lambda \in \left(0, \frac{2\alpha}{L^2}\right)$. It is known (see, e.g., Xiu & Zhang, 2003) that under some mild conditions, algorithm (1.3) satisfied strong convergence condition and has a unique solution. However, if $\mathcal{A}$ is inverse strongly monotone, it has a weak convergence.
In order to avoid this strong assumption on $\mathcal{A}$, ($\alpha - ism$), Korpelevich (1976) introduced the so called extragradient method which is of the form:

$$\begin{cases} y_n = P_C(x_n - \lambda \mathcal{A} x_n), \\ x_{n+1} = P_C(x_n - \lambda \mathcal{A} y_n), n \geq 0, \end{cases} \tag{1.4}$$

where $\lambda \in \left(0, \frac{1}{L}\right)$ and the operator $\mathcal{A}$ is monotone and Lipschitz continuous.
It is obvious that the algorithm (1.4) of Korpelevich involves computation of two projections of closed and convex set C per iteration while a weaker assumption on $\mathcal{A}$ (monotone and Lipschitz continuous) has been introduced. If the feasible set has a complicated structure, then the algorithm (1.4) will be difficult to implement. Moreover, projection onto a feasible set has by default, ways of slowing the rate of convergence.
To improve on this result (Korpelevich, 1976), Censor et al. (2011) introduced an improved version, called subgradient extragradient method which has the following architecture:

$$\begin{cases} y_n = P_C(x_n - \lambda \mathcal{A} x_n), \\ T_n = \{w \in \mathcal{H}: \langle x_n - \lambda \mathcal{A} x_n - y_n, w - y_n \rangle \leq 0\}, \\ x_{n+1} = P_{T_n}(x_n - \lambda \mathcal{A} y_n), n \geq 0, \end{cases} \tag{1.5}$$

where $\lambda \in \left(0, \frac{1}{L}\right)$ and the second projection (P_{T_n}) which is onto a specific constructive half-space. This type of projection is very easy to compute. Although, algorithm (1.5) involves two

projections, it is still a big advantage over algorithm (1.4) since P_{T_n} is simple. The authors obtained a weak convergence.
Based on the fact that every researcher is particularly interested on the fast convergence, the need to drop one of the projections necessitated Tseng (2000) to construct the following algorithm for solving (1.1). For initial point $x_0 \in \mathcal{H}$, compute x_{n+1} via the formula:

$$\begin{cases} y_n = P_C(x_n - \lambda \mathcal{A} x_n), \\ x_{n+1} = y_n - \lambda(\mathcal{A} y_n - \mathcal{A} x_n), \ \ \forall n \geq 0, \end{cases} \tag{1.6}$$

where $\lambda \in \left(0, \frac{1}{L}\right)$ and the algorithm satisfies a weak convergence criterion. One sees that the algorithm (1.6) computes one projection per iteration which is a huge improvement on the algorithms (1.3) to (1.5).

Sun, (1996) and He (1997) independently introduced and studied projection and contraction algorithms for solving (1.1). The projection and contraction algorithm has the following structure:

$$\begin{cases} y_n = P_C(x_n - \lambda \mathcal{A} x_n), \\ d(x_n, y_n) = x_n - y_n - \lambda(\mathcal{A} x_n - \mathcal{A} y_n), \\ x_{n+1} = x_n - \gamma \eta_n d(x_n, y_n), \ \forall \, n \geq 0, \end{cases} \tag{1.7}$$

where $\lambda \in \left(0, \frac{1}{L}\right), \gamma \in (0,2)$ and

$$\eta_n = \frac{\langle x_n - y_n, d(x_n, y_n) \rangle}{\|d(x_n, y_n)\|^2}, n \geq 0.$$

The projection and contraction method also requires only one step iteration onto the feasible set C in each of iteration and the recursive sequence $\{x_n\}$ generated by algorithm 1.7 is proven to have a weak convergence.
The simple reason for all these modification of algorithm (1.4) is to establish fast convergence which is of paramount interest of many researchers. Apart from this level of modifications, there are two ways for achieving fast convergence: the inertial term and relaxation method. But our focus is on the inertial, a concept introduced and studied by Polyak (1964) which is based upon a discrete version of a second order dissipative dynamical system. Many researchers have incorporated this technique into algorithms for solving different optimizations problems; see e.g., Ezeora et al. 2023; Nwawuru & Ezeora, 2023 and cited references therein.
Remark 1.1: We observe the following setbacks in the mentioned methods:

1) All the algorithms (algorithm 1.3 to 1.7) mentioned, the stepsize which plays an important role in the convergence analysis depends of the Lipschitz constant. It is generally known that computing or estimating the value of Lipschitz constant in a difficult task. And in many practical cases, impossible to achieve.
2) The stepsize λ is fixed, as a matter of necessity; variable stepsizes are always desirable in applications. Thus, the fixed stepsize has lots to limitations as it does not give the optimal result.

3) The monotone and Lipschitz continuity have been involved in the algorithms (algorithms 1.4 to 1.7). This is a smaller class of operator as a result many other contemporary problems might be left out.
4) Also, apart from the strong convergence result obtained in algorithm (1.3) on a condition that the nonlinear operator $\mathcal{A}$ is an α −inverse strongly monotone, others (algorithm 1.4 to 1.7) produce weak convergence result when the operator $\mathcal{A}$ is monotone and Lipschitz continuous. Strong convergence is always profitable and desirable.

To improve on the above highlighted challenges, many researchers have constructed different algorithms in different ways. To this end, Cholamjiak et al. (2020), constructed an algorithm and established a strong convergence on a condition that the operator $\mathcal{A}$ is Lipschitz continuous and pseudomonotone and would further satisfy sequential weakly continuity assumption. Furthermore, Tian and Xu (2021) constructed a different inertial-based algorithm, using projection and contraction method for solving variational inequality problem with a condition that the operator $\mathcal{A}$ is Lipschitz continuous and pseudomonotone and would further satisfy sequential weakly continuity assumption as well. There are other algorithms involving pseudomonotonicity and Lipschitz continuity assumptions, see e.g., Dong el at. (2018), Cai et al. (2021) and cited references therein.

Remarkably, Tan and Li (2022) came up with two novel improved version of projection and contraction algorithm for solving the variational inequality problem (1.1). In fact, they presented the following two algorithms:

Algorithm 3.1: Take $\alpha, \rho > 0, \ell, \eta \in (0,1), \psi \in \left(0, \frac{2}{\eta}\right)$, and $\beta \in \left(\frac{\psi}{2}, \frac{1}{\eta}\right)$. Given the current iterates x_n and $x_{n-1} (n \geq 1)$ and compute as follows:

$$\begin{cases} u_n = (1-\tau_n)(x_n + \alpha_n(x_n - x_{n-1}), \\ d_n = Proj_C(u_n - \beta\chi_n Q u_n), \\ x_{n+1} = Proj_{H_n}(u_n - \Psi\chi_n\gamma_n Q d_n), \end{cases} \tag{1.8}$$

where

$$\alpha_n = \begin{cases} \min\left\{\frac{\zeta_n}{\|x_n - x_{n-1}\|}, \alpha\right\}, if\, x_n \neq x_{n-1}; \\ \alpha, \qquad\qquad otherwise \end{cases},$$

χ_n is chosen to be the largest $\chi \in \{\rho, \rho\ell, \rho\ell^2, \dots\}$ satisfying

$$\chi\|Qu_n - Qd_n\| \leq \eta\|u_n - d_n\|,$$

$$H_n = \{x \in \mathcal{H} | \langle u_n - \beta\chi_n Q u_n - d_n, x - d_n\rangle \leq 0\},$$

and

$$\gamma_n = (1-\beta\eta)\frac{\|u_n - d_n\|^2}{\|\delta_n\|^2}, \delta_n = u_n - d_n - \beta\chi_n(Qu_n - Qd_n).$$

Algorithm 3.2: Take $\alpha, \rho > 0, \ell, \eta \in (0,1), \psi \in \left(0, \frac{2}{\eta}\right)$, and $\beta \in \left(\frac{\psi}{2}, \frac{1}{\eta}\right)$. Given the current iterates x_n and $x_{n-1} (n \geq 1)$ and compute as follows:

$$\begin{cases} u_n = (1-\tau_n)(x_n + \alpha_n(x_n - x_{n-1}), \\ d_n = Proj_C(u_n - \beta\chi_n Q u_n), \\ x_{n+1} = u_n - \Psi\gamma_n\delta_n, \end{cases}$$
(1.9)

where the parameters have their usual definitions as in Algorithm 3.1 above.

In both Algorithm (1.8) and (1.9), the operator $Q: \mathcal{H} \to \mathcal{H}$ is pseudo-monotone, uniformly continuous and sequentially weakly continuous on the nonempty, closed and convex set C. The sequence $\{\zeta_n\}$ is positive such that $\lim_{n\to\infty} \frac{\zeta_n}{\tau_n} = 0$, where $\{\tau_n\} \subset (0,1)$ satisfies $\lim_{n\to\infty} \tau_n = 0$ and $\sum_{n=1}^{\infty} \tau_n = \infty$. Provided the solution set $VI(C,Q) \neq \emptyset$, the authors in both algorithms (Algorithm 1.8 and 1.9), proved that the iterative sequence $\{x_n\}$ generated by algorithms (1.8) and (1.9) converge strongly to point $x^* \in VI(C,Q)$.

Question of interest: Can we recover the strong convergence criterion with a simple algorithm which involves quasi-monotone operator and does not satisfy the sequential weakly continuity assumptions imposed on the mentioned algorithms? It is our primary aim to provide an affirmative answer to the problem.

Our contributions: We shall make the following contributions to literature:

a. To construct a simple algorithm for solving variational inequalities that the underline operator is quasi-monotone which is more general than being monotone and pseudo-monotone used in Cholamjiak et al. (2020), Tian and Xu (2021), Dong el at. (2018), Cai et al. (2021), Tan and Li (2022) among many others. More so, to keep the control parameters minimal unlike Algorithm 3.1 and 3.2 of Tan and Li (2022). Most of these parameters also contribute to slow rate of convergence.
b. To obtain a strong convergence result on assumption that the operator $\mathcal{A}$ satisfies the following weaker condition that is; whenever $\{x_n\} \subset C, x_n \rightharpoonup x^*$, we get $\|\mathcal{A}x^*\| \leq \lim_{n\to\infty}\inf\|\mathcal{A}x_n\|$ instead of sequential weakly continuous (see, e.g., Tan & Li, 2022; Tian & Xu, 2021).
c. To incorporate an inertial term technique that is known to speed up the rate of convergence. Also, to involve a variable stepsize that is self-adaptive and updates at each iteration.
d. To construct efficient algorithm that involves computation of one step projection onto the feasible per iteration. Furthermore, we do not need prior information of the Lipschitz constant in our convergence analysis.

The remaining part of the paper is organized as follows: Section two deals with basic definitions and presentations of relevant Lemmas. In section three, we state assumptions on both the operator and control sequences and equally construct our algorithm. Section four deals with the technical proof of the proposed method. Immediate corollaries will be discussed in the section five. Section six and seven will be concerned with applications of our result to other related problems and the concluding remarks respectively.

2. Preliminary

Let $\mathcal{H}$ be a real Hilbert space and C a nonempty, closed and convex subset of $\mathcal{H}$. Let the inner product associated with $\mathcal{H}$ be denoted by $\langle .,. \rangle$ an induced norm be represented by $\|.\|$, and

$\mathcal{A}: \mathcal{H} \to \mathcal{H}$ be a nonlinear operator. We denote the strong and weak convergence with " $\to$ " and " $\rightharpoonup$ " respectively.

Definition 2.1(Zegeye, 2015)**:** Let $\mathcal{H}$ be a real Hilbert space and C a nonempty, closed and convex subset of $\mathcal{H}$. Let $\mathcal{F}: \mathcal{H} \to \mathcal{H}$ be a real single-valued mapping. Then, for $x, y \in \mathcal{F}$, $\mathcal{F}$ is said to be:

1) L −Lipschitz continuous, if there exists $L > 0$ such that
$$\|\mathcal{F}x - \mathcal{F}y\| \leq L\|x - y\|;$$
2) Nonexpansive if
$\|\mathcal{F}x - \mathcal{F}y\| \leq \|x - y\|.$

Definition 2.2(Thong et al., 2020)**:** Let $\mathcal{H}$ be a real Hilbert space and C a nonempty, closed and convex subset of $\mathcal{H}$. Let $\mathcal{A}: \mathcal{H} \to \mathcal{H}$ be a real single-valued mapping. Then, for $x, y \in \mathcal{F}$, $\mathcal{F}$ is said to be:

1) β −strongly monotone, if there exists $\beta > 0$ such that
$\langle \mathcal{A}x - \mathcal{A}y, x - y\rangle \geq \beta\|x - y\|^2$ for all $x, y \in \mathcal{H}$;
2) Monotone, if
$\langle \mathcal{A}x - \mathcal{A}y, x - y\rangle \geq 0, \forall x, y \in \mathcal{H}$;
3) Pseudomonotone, if
$$\langle \mathcal{A}y, x - y\rangle \geq 0 \Longrightarrow \langle \mathcal{A}x, x - y\rangle \geq 0, \forall\, x, y \in \mathcal{H};$$
4) Quasi-monotone, if
$$\langle \mathcal{A}x, x - y\rangle > 0 \Longrightarrow \langle \mathcal{A}y, x - y\rangle \geq 0, \forall x, y \in \mathcal{H}.$$

Remark 2.1: In the definition 2.1, we observe that whenever the Lipschitz constant $L = 1$, we obtain a nonexpansive mapping from the Lipschitz continuity. Also, from the definition 2.2, we summarize that
$$(1) \Longrightarrow (2) \Longrightarrow (3) \Longrightarrow (4).$$
Therefore, the class of quasi-monotone is more general than the others mentioned but the converse is not always true.

For each $x \in \mathcal{H}$, there exists a unique nearest point in C denoted by $P_C x$ such that
$$\|x - P_C x\| = \inf\{\|x - y\|: y \in C\}.$$
The operator P_C is called the metric projection of $\mathcal{H}$ onto C. It is a known result that the P_C is not only nonexpansive mapping but also firmly nonexpansive. It is further characterized by the following lemma.

Lemma 2.3 (He et al., 2014): Let $P_C: \mathcal{H} \to C$ be the metric projection of $\mathcal{H}$ onto C. Then, the following hold: For all $x, y \in \mathcal{H}$,

(1) $\|P_C x - P_C y\|^2 \leq \langle P_C x - P_C y, x - y\rangle$;
(2) $z = P_C x$ if and only if $\langle x - z, \omega - z\rangle \leq 0, \forall\, \omega \in C$;
(3) $\|x - P_C y\|^2 + \|P_C y - y\|^2 \leq \|x - y\|^2$.

Lemma 2.4 (Ugwunnadi et al., 2022)**:** Let $\mathcal{H}$ be a real Hilbert space, $x, y \in \mathcal{H}$ and $\lambda \in \mathbb{R}$, then the following hold:

1. $2\langle x, y\rangle = \|x\|^2 + \|y\|^2 - \|x - y\|^2 = \|x + y\|^2 - \|x\|^2 - \|y\|^2$;
2. $\|x - y\|^2 \leq \|x\|^2 + 2\langle y, x - y\rangle$;
3. $\|\lambda x + (1 - \lambda)y\|^2 = \lambda\|x\|^2 + (1 - \lambda)\|y\|^2 - \lambda(1 - \lambda)\|x - y\|^2$.

The following lemma is essential and associated with L −Lipschitzian and quasi-monotone operator.

Lemma 2.5 (Zheng, 2018; Hadjisavvas & Schaible, 1996**):** Let C be a nonempty, closed and convex subset of a Hilbert space $\mathcal{H}$ and $\mathcal{A}: \mathcal{H} \to \mathcal{H}$ be L −Lipschitzian and quasi-monotone operator. Let $y \in C$. If for some $x^* \in C$, we have that $\langle \mathcal{A}(y), x^* - y \rangle \geq 0$, then at least one of the following must hold:

$\langle \mathcal{A}(x^*), x^* - y \rangle \geq 0$ or $\langle \mathcal{A}(y), z^* - y \rangle \leq 0, \forall z^* \in C.$

Lemma 2.6 (Ezeora et al., 2023): Let $\{\varphi_n\}$ be a sequence of positive real numbers. Let δ_n and ρ_n be sequences in $(0,1)$ with $\sum_{n=1}^{\infty} \delta_n = \infty$. Suppose that $\{\varphi_n\}$ satisfies the inequality:

$$\varphi_{n+1} \leq (1 - \delta_n)\varphi_n + \delta_n \rho_n, \forall n \geq 1.$$

If the $\lim_{j \to \infty} sup\, \rho_{n_j} \leq 0$ for every subsequence $\{\varphi_{n_j}\}$ of $\{\varphi_n\}$ satisfying the condition $\lim_{j \to \infty} \inf(\varphi_{n_j} - \varphi_{n_j+1}) \geq 0$. Then, $\lim_{n \to \infty} \varphi_n = 0$.

3. The Proposed Method: Accelerated Projection and Contraction Algorithm

The following assumptions shall be considered:

Assumption 3.1: Suppose that:

a) The feasible set C is nonempty, closed and convex.
b) The operator $\mathcal{A}: \mathcal{H} \to \mathcal{H}$ is quasi-monotone, and L −Lipschitz continuous and satisfies the condition that whenever $\{x_n\} \subset C, x_n \rightharpoonup x^*$, we get $\|\mathcal{A}x^*\| \leq \lim_{n \to \infty} \inf \|\mathcal{A}x_n\|$.
c) The solution set $VIP(C, \mathcal{A}) \neq \emptyset$.

Assumption 3.2: The control sequences shall satisfy the following:

i) The sequence $\{\tau_n\}$ is positive such that $\tau_n = o\beta_n$, which means $\lim_{n \to \infty} \frac{\tau_n}{\beta_n} = 0$ and $\alpha_n \subset (a, 1 - \beta_n)$ for some $a > 0$ where $\{\beta_n\} \subset (0,1)$ satisfies the following conditions: $\lim_{n \to \infty} \beta_n = 0$, and $\sum_{n=1}^{\infty} \beta_n = \infty$.
ii) $0 \leq \theta \leq \theta_n \leq \overline{\theta_n}$ where

$$\overline{\theta_n} := \begin{cases} \min\left\{\dfrac{\theta}{2}, \dfrac{\tau_n}{\|x_n - x_{n-1}\|}\right\}, if\ x_n \neq x_{n-1}, \\ \dfrac{\theta}{2}, \qquad otherwise. \end{cases}$$

iii) $\lambda_{n+1} = \begin{cases} \min\left\{\frac{\mu\|w_n - y_n\|}{\|\mathcal{A}w_n - \mathcal{A}y_n\|}, \lambda_n\right\}, if\ \mathcal{A}w_n \neq \mathcal{A}y_n, \\ \lambda_n, \qquad otherwise. \end{cases}$

Algorithm 3.3: Given $\mu \in (0,1), \theta \in [0,1), \eta > 0$. Let $x_0, x_1 \in C$.

Iterative steps: Given the current iterate $x_n, x_{n-1}, (n \geq 1)$, we compute as follows:

Step 1: $\begin{cases} w_n = x_n + \theta_n(x_n - x_{n-1}), \\ y_n = P_C(w_n - \lambda_n \mathcal{A} w_n), \end{cases}$

(3.1)

If $y_n = w_n$, then stop, y_n is the solution of the VIP. Otherwise, go to step 2.

Step 2: Construct

$$d(w_n, y_n) = w_n - y_n - \lambda_n(\mathcal{A}w_n - \mathcal{A}y_n), \sigma_n = \frac{\langle w_n - y_n, d(w_n, y_n)\rangle}{\|d(w_n, y_n)\|^2},$$

and compute

$$z_n = w_n - \eta\sigma_n d(w_n, y_n).$$

Step 3: Evaluate x_{n+1} via the formula:

$$x_{n+1} = (1 - \alpha_n - \beta_n)x_n + \alpha_n z_n$$

Set n:=n+1 and return to step 1.

Remark 3.1: From the Assumptions 3.1 and 3.2 and the Algorithm 3.3, we highlight the following features of our algorithm.

i) The nonlinear operator $\mathcal{A}$ is quasi-monotone and Lipschitz continuous (see remark 2.1). Instead of strong assumption of satisfying sequentially weakly continuity assumption (see, e.g., Tan & Li, 2022; Tian & Xu, 2021), we consider a weaker assumption (see the Assumption 3.1(b)).

ii) The stepsize λ_n is variable and self-adaptive unlike the works of Censor et al. 2011, Tseng, 2000, Sun, (1996) and He (1997) whose stepsize depend on the Lipschitz constant.

iii) Our Algorithm (Algorithm 3.3) involves computing one projection onto the feasible set C unlike Tan and Li (2022). The iterative sequence $\{x_n\}$ generated by our algorithm satisfies strong convergence conditions.

iv) The control sequences involved in our algorithm is quite minimal unlike Algorithms 1.8 and 1.9 of Tan and Li (2022). Our method of prove is unique and elegant.

4. The Convergence Analysis.

Before we proceed, the following remark is very essential in the proving process.

Remark 4.1: From the Assumption 3.2, we see that $\lambda_{n+1} \leq \lambda_n, \forall n \geq 1$.

Also, if $\mathcal{A}w_n \neq \mathcal{A}y_n$, then

$\|\mathcal{A}w_n - \mathcal{A}y_n\| \leq L\|w_n - y_n\| \Longrightarrow \frac{1}{\|\mathcal{A}w_n - \mathcal{A}y_n\|} \geq \frac{1}{L\|w_n - y_n\|}$.

It follows from this fact that

$$\frac{\mu\|w_n - y_n\|}{\|\mathcal{A}w_n - \mathcal{A}y_n\|} \geq \frac{\mu}{L}.$$

We obtain from this argument that

$$\lambda_{n+1} = \min\left\{\frac{\mu\|w_n - y_n\|}{\|\mathcal{A}w_n - \mathcal{A}y_n\|}, \lambda_n\right\} \geq \min\left\{\frac{\mu}{L}, \lambda_n\right\}$$

which further implies that

$$\min\left\{\frac{\mu}{L}, \lambda_n\right\} \leq \lambda_{n+1} \leq \lambda_n, \forall n \geq 1.$$

One sees that $\lambda_n \leq \lambda_1, \forall n \geq 1$ since λ_n is monotone nonincreasing sequence. Thus, $\min\left\{\frac{\mu}{L}, \lambda_n\right\} \leq \lambda_{n+1}$, which implies that
$\min\left\{\frac{\mu}{L}, \lambda_n\right\} \leq \lambda_2$ and so, $\min\left\{\frac{\mu}{L}, \lambda_2\right\} \leq \lambda_3$.
Hence,
$\min\left\{\min\left\{\frac{\mu}{L}, \lambda_1\right\}, \frac{\mu}{L}\right\} \leq \min\left\{\frac{\mu}{L}, \lambda_2\right\} \leq \lambda_3$.
It follows that $\min\left\{\frac{\mu}{L}, \lambda_3\right\} \leq \lambda_4$.
We generalized that
$\min\left\{\min\left\{\frac{\mu}{L}, \lambda_1\right\}, \frac{\mu}{L}\right\} \leq \min\left\{\frac{\mu}{L}, \lambda_3\right\} \leq \lambda_4$, that is, $\min\left\{\frac{\mu}{L}, \lambda_1\right\} \leq \lambda_4$.
Continuing in this way, we obtain

$$0 < min\left\{\frac{\mu}{L}, \lambda_1\right\} \leq \lambda_n, \forall n \geq 1.$$

Therefore, $0 < \lambda = \lim_{n\to\infty} \lambda_n$ exist.

Theorem 4.2: Let $\{x_n\}$ be a sequence generated by algorithm 3.3 satisfying Assumptions 3.1 and 3.2. Then $\{x_n\}$ converges strongly to an element $p \in \Gamma := VIP(C, \mathcal{A})$, where

$$\|p\| = \min\{\|z\|: z \in VIP(C, \mathcal{A})\}.$$

Proof: To establish this result, we split it into different Lemmas.

Lemma 4.3: Let $\{z_n\}$ be a sequence generated by the Algorithm 3.3 and such that Assumptions 3.1 and 3.2 are satisfied. Then, $\{z_n\}$ satisfies the following inequality:
$\|z_n - q\|^2 \leq \|w_n - q\|^2 - \frac{2-\eta}{\eta}\|z_n - w_n\|^2$.

Proof: Choose a point $q \in \Gamma$. Since, $y_n \in C$, then, $\langle \mathcal{A}q, y_n - q\rangle \geq 0$. Also, due to the fact that $\mathcal{A}$ is an operator in C, by applying Lemma 2.5, we obtain

$$\langle \mathcal{A}y_n, y_n - q\rangle \geq 0. \tag{4.1}$$

Applying Lemma 2.3(2) (characterization of the metric projection P_C), we have

$$\langle w_n - y_n - \lambda_n(\mathcal{A}w_n), y_n - q\rangle \geq 0.$$
(4.2)

Combining (4.1) and (4.2), one gets

$$\langle w_n - y_n - \lambda_n(\mathcal{A}w_n - \mathcal{A}y_n), y_n - q\rangle \geq 0.$$
(4.3)

Using the definition of $d(w_n, y_n)$ from Algorithm 3.3 and (4.3), we obtain

$$\langle d(w_n, y_n), y_n - q\rangle \geq 0.$$
(4.4)

Observe that

$$\langle w_n - q, d(w_n, y_n)\rangle = \langle w_n - y_n + y_n - q, d(w_n, y_n)\rangle$$
$$= \langle w_n - y_n, (w_n, y_n)\rangle + \langle y_n - q, d(w_n, y_n)\rangle$$
(4.5)
$$= \langle w_n - y_n, (w_n, y_n)\rangle + \langle y_n - q, w_n - y_n - \lambda_n(\mathcal{A}w_n - \mathcal{A}y_n)\rangle$$

We know from the step 1 of the Algorithm 3.3 that $y_n = P_C(w_n - \lambda_n \mathcal{A}w_n)$. It follows from this fact and (4.5) that

$$\langle y_n - q, w_n - y_n - \lambda_n(\mathcal{A}w_n - \mathcal{A}y_n)\rangle \geq 0.$$
(4.6)

Now, combining (4.4), (4.5) and (4.6) to obtain

$$\langle w_n - q, d(w_n, y_n)\rangle \geq \langle w_n - y_n, d(w_n, y_n)\rangle.$$
(4.7)

Now a point $q \in \Gamma$, we compute as follows:

$$\|z_n - q\|^2 = \|w_n - \eta\sigma_n d(w_n, y_n) - q\|^2$$
$$= \|w_n - q\|^2 + (\eta\sigma_n)^2\|d(w_n, y_n)\|^2 - 2\eta\sigma_n\langle w_n - q, d(w_n, y_n)\rangle$$
$$= \|w_n - q\|^2 + (\eta\sigma_n)^2\|d(w_n, y_n)\|^2 - 2\eta\sigma_n\langle w_n - y_n + y_n - q, d(w_n, y_n)\rangle$$
$$= \|w_n - q\|^2 + (\eta\sigma_n)^2\|d(w_n, y_n)\|^2 - 2\eta\sigma_n\langle w_n - y_n, d(w_n, y_n)\rangle$$
$$-2\eta\sigma_n\langle y_n - q, d(w_n, y_n)\rangle$$
(4.8)
$$\leq \|w_n - q\|^2 + (\eta\sigma_n)^2\|d(w_n, y_n)\|^2 - 2\eta\sigma_n\langle w_n - y_n, d(w_n, y_n)\rangle$$

From the Algorithm that

$\sigma_n = \frac{\langle w_n - y_n, d(w_n, y_n)\rangle}{\|d(w_n, y_n)\|^2}$, if $\|d(w_n, y_n)\|^2 \neq 0$,

which implies that

$$\sigma_n\|d(w_n, y_n)\|^2 = \langle w_n - y_n, d(w_n, y_n)\rangle$$
(4.9)

Using (4.9) in (4.8), we obtain

$$\|z_n - q\|^2 \leq \|w_n - q\|^2 - 2\eta\sigma_n^2\|d(w_n, y_n)\|^2 + (\eta\sigma_n)^2\|d(w_n, y_n)\|^2$$
$$= \|w_n - q\|^2 - (2-\eta)\eta\|\sigma_n d(w_n, y_n)\|^2$$

(4.10)

Furthermore, from the step 2 of the Algorithm 3.3, we see that

$$\frac{z_n - w_n}{\eta} = -\sigma_n\|d(w_n, y_n)\|,$$

which further implies that

$$\frac{\|z_n - w_n\|}{\eta} = \|\sigma_n d(w_n, y_n)\|,$$

(4.11)

Invoking (4.11) into (4.10), we get

$$\|z_n - q\|^2 \leq \|w_n - q\|^2 - \frac{2-\eta}{\eta}\|z_n - w_n\|^2.$$

(4.12)

This completes the proof of Lemma 4.3.■

Lemma 4.4: Let $\{w_n\}$ and $d(w_n, y_n)$ be sequences generated by the Algorithm 3.3, and $d(w_n, y_n) = 0$ if and only if $w_n = y_n$ for all $n \geq 1$, then $w_n = y_n$, so, $y_n = P_C(y_n - \lambda_n \mathcal{A}\lambda_n), n \geq 1$, this implies that $y_n \in VIP(C, \mathcal{A})$. Furthermore, there exists $n_0 \geq 1$ such that

$$\|w_n - y_n\|^2 \leq \left[\frac{1+\mu}{(1-\mu)\eta}\right]^2 \|z_n - w_n\|^2, \forall n \geq n_n\,.$$

Proof: From the definition of $d(w_n, y_n)$ in the step 2 of Algorithm 3.3, and Assumption 3.2 (iii) we obtain

$$\begin{aligned}\|d(w_n, y_n)\| &= \|w_n - y_n - \lambda_n(\mathcal{A}w_n - \mathcal{A}y_n)\| \\ &\geq \|w_n - y_n\| - \lambda_n\|\mathcal{A}w_n - \mathcal{A}y_n\| \\ &\geq \|w_n - y_n\| - \mu\frac{\lambda_n}{\lambda_{n+1}}\|w_n - y_n\| \\ &= \left(1 - \mu\frac{\lambda_n}{\lambda_{n+1}}\right)\|w_n - y_n\|.\end{aligned}$$

(4.13)

It follows from (4.13) that

$$\left(1 - \mu\frac{\lambda_n}{\lambda_{n+1}}\right)\|w_n - y_n\| \leq \|d(w_n, y_n)\|.$$

(4.14)

On the other hand, we also observe that

$$\begin{aligned}\|d(w_n, y_n)\| &= \|w_n - y_n - \lambda_n(\mathcal{A}w_n - \mathcal{A}y_n)\| \\ &\leq \|w_n - y_n\| + \lambda_n\|\mathcal{A}w_n - \mathcal{A}y_n\| \\ &\leq \|w_n - y_n\| + \mu\frac{\lambda_n}{\lambda_{n+1}}\|w_n - y_n\| \\ &= \left(1 + \mu\frac{\lambda_n}{\lambda_{n+1}}\right)\|w_n - y_n\|\end{aligned}$$

(4.15)

Using (4.14) and (4.15), we establish that

$$\left(1-\mu\frac{\lambda_n}{\lambda_{n+1}}\right)\|w_n-y_n\|\le\|d(w_n,y_n)\|\le\left(1+\mu\frac{\lambda_n}{\lambda_{n+1}}\right)\|w_n-y_n\| \quad (4.16)$$

Recall from remark 4.1 that $0<\lambda=\lim_{n\to\infty}\lambda_n$. Using this fact, we have

$\lim_{n\to\infty}\left(1-\mu\frac{\lambda_n}{\lambda_{n+1}}\right)=(1-\mu)>0$ and $\lim_{n\to\infty}\left(1+\mu\frac{\lambda_n}{\lambda_{n+1}}\right)=(1+\mu)>0.$

Considering these facts on (4.16), we establish that

$$(1-\mu)\|w_n-y_n\|\le\|d(w_n,y_n)\|\le(1+\mu)\|w_n-y_n\|, \quad (4.17)$$

completing a part of the Lemma 4.4.

Also, from (4.17), we have

$$\frac{1}{\|\|d(w_n,y_n)\|\|^2}\ge\frac{1}{(1+\mu)^2\|w_n-y_n\|^2}. \quad (4.18)$$

Furthermore, we have from the Algorithm that

$$\sigma_n=\frac{\langle w_n-y_n,d(w_n,y_n)\rangle}{\|d(w_n,y_n)\|^2},$$

that is,

$$\begin{aligned}\sigma_n\|d(w_n,y_n)\|^2&=\langle w_n-y_n,d(w_n,y_n)\rangle\\&=\langle w_n-y_n,w_n-y_n-\lambda_n(\mathcal{A}w_n-\mathcal{A}w_n)\rangle\\&=\|w_n-y_n\|^2-\lambda_n\langle w_n-y_n,\mathcal{A}w_n-\mathcal{A}w_n\rangle\\&\ge\|w_n-y_n\|^2-\lambda_n\|w_n-y_n\|\|\mathcal{A}w_n-\mathcal{A}w_n\|\\&\ge\|w_n-y_n\|^2-\mu\frac{\lambda_n}{\lambda_{n+1}}\|w_n-y_n\|^2\\&=\left(1-\mu\frac{\lambda_n}{\lambda_{n+1}}\right)\|w_n-y_n\|^2.\end{aligned} \quad (4.19)$$

It follows from (4.19), $\lim_{n\to\infty}\left(1-\mu\frac{\lambda_n}{\lambda_{n+1}}\right)=(1-\mu)>0,\forall n\ge n_0$, and (4.18) that

$\sigma_n\ge\frac{1-\mu}{(1+\mu)^2}\ ,\forall n\ge n_0,$

that is,

$$\frac{1}{\sigma_n}\le\frac{(1+\mu)^2}{1-\mu}. \quad (4.20)$$

From (4.19),

$$\begin{aligned}\|w_n-y_n\|^2&\le\frac{\sigma_n}{1-\mu}\|d(w_n,y_n)\|^2\\&=\frac{\|\eta\sigma_n d(w_n,y_n)\|^2}{1-\mu}\times\frac{1}{\sigma_n}\times\frac{1}{\eta^2}\\&=\frac{1}{1-\mu}\|z_n-w_n\|^2\times\frac{1}{\sigma_n}\times\frac{1}{\eta^2}\end{aligned} \quad (4.21)$$

Using the estimate in (4.20) and (4.21), we obtain

$$\|w_n - y_n\|^2 \le \frac{1}{1-\mu}\|z_n - w_n\|^2 \times \frac{(1+\mu)^2}{1-\mu} \times \frac{1}{\eta^2}$$
$$= \left[\frac{1+\mu}{(1-\mu)\eta}\right]^2 \|z_n - w_n\|^2 .$$

(4.22)

This completes the proof of Lemma 4.4■

Lemma 4.5: Let $\{x_n\}$ be a sequence generated by the Algorithm 3.3 satisfying Assumptions 3.1 and 3.2, then, $\{x_n\}$ is bounded.

Proof: Let $q \in \Gamma$. By the definition of w_n, we get

$$\|w_n - q\| = \|x_n + \theta_n(x_n - x_{n-1}) - q\|$$
$$\le \|x_n - q\| + \theta_n\|x_n - x_{n-1}\|$$
$$= \|x_n - q\| + \beta_n \frac{\theta_n}{\beta_n}\|x_n - x_{n-1}\|.$$

(4.23)

Now, using Assumption 3.2(ii), we get

$\frac{\theta_n}{\beta_n}\|x_n - x_{n-1}\| \le \frac{\tau_n}{\beta_n}$, i.e.,

$\lim\limits_{n\to\infty} \frac{\theta_n}{\beta_n}\|x_n - x_{n-1}\| = 0$, it follows that the sequence $\left\{\frac{\theta_n}{\beta_n}\|x_n - x_{n-1}\|\right\}$ is bounded. Using this fact, we therefore conclude that there exists a constant $K_0 > 0$ such that

$\frac{\theta_n}{\beta_n}\|x_n - x_{n-1}\| \le K_0$ for all $n \ge 1$.

Thus, following (4.23), we obtain

$$\|w_n - q\| \le \|x_n - q\| + \beta_n K_0.$$

(4.24)

Using the definition of x_{n+1} from the Algorithm 3.3, Lemma 4.3 and the estimate in (4.24), we have

$$\|x_{n+1} - q\| = \|(1-\alpha_n-\beta_n)x_n + \alpha_n z_n - q\|$$
$$= \|(1-\alpha_n-\beta_n)(x_n - q) + \alpha_n(z_n - q) - \beta_n q\|$$
$$\le \|(1-\alpha_n-\beta_n)(x_n - q) + \alpha_n(z_n - q)\| + \beta_n\|q\|.$$

(4.25)

Observe that

$$\|(1-\alpha_n-\beta_n)(x_n - q) + \alpha_n(z_n - q)\|^2$$
$$= (1-\alpha_n-\beta_n)^2\|x_n - q\|^2 + 2\alpha_n(1-\alpha_n-\beta_n)\langle x_n - q, z_n - q\rangle$$
$$+\alpha_n^2\|z_n - q\|^2$$
$$\le (1-\alpha_n-\beta_n)^2\|x_n - q\|^2 + 2\alpha_n(1-\alpha_n-\beta_n)\|x_n - q\|\|z_n - q\|$$
$$+\alpha_n^2\|z_n - q\|^2$$
$$\le (1-\alpha_n-\beta_n)^2\|x_n - q\|^2 + \alpha_n(1-\alpha_n-\beta_n)\|x_n - q\|^2$$
$$+\alpha_n(1-\alpha_n-\beta_n)\|z_n - q\|^2 + \alpha_n^2\|z_n - q\|^2$$

$$= (1-\alpha_n-\beta_n)(1-\beta_n)\|x_n-q\|^2 + (1-\beta_n)\|z_n-q\|^2.$$
(4.26)

Substituting (4.24) into (4.26) to obtain

$$\begin{aligned}
&\|(1-\alpha_n-\beta_n)(x_n-q)+\alpha_n(z_n-q)\|^2 \\
&\quad \le (1-\alpha_n-\beta_n)(1-\beta_n)\|x_n-q\|^2 \\
&\quad +\alpha_n(1-\beta_n)(\|x_n-q\|+\beta_n K_0)^2 \\
&\quad \le (1-\alpha_n-\beta_n)(1-\beta_n)\|x_n-q\|^2+\alpha_n(1-\beta_n)\|x_n-q\|^2 \\
&\quad +2\alpha_n\beta_n(1-\beta_n)\|x_n-q\|K_0+(\beta_n K_0)^2 \\
&\quad \le (1-\beta_n)^2\|x_n-q\|^2+2\alpha_n(1-\beta_n)\|x_n-q\|K_0+(\beta_n K_0)^2 \\
&\quad = [(1-\beta_n)\|x_n-q\|^2+\beta_n K_0]^2.
\end{aligned}$$
(4.27)

Therefore, we have from (4.27) that

$$\|(1-\alpha_n-\beta_n)(x_n-q)+\alpha_n(z_n-q)\| \le (1-\beta_n)\|x_n-q\|+\beta_n K_0.$$
(4.28)

Combining (4.25) and (4.28)

$$\begin{aligned}
\|x_{n+1}-q\| &\le (1-\beta_n)\|x_n-q\|^2+\beta_n K_0+\beta_n\|q\| \\
&= (1-\beta_n)\|x_n-q\|+\beta_n(K_0+\|q\|) \\
&\le \max\{\|x_n-q\|, K_0+\|q\|\} \\
&\le \cdots \le \max\{\|x_0-q\|, K_0+\|q\|\}.
\end{aligned}$$
(4.29)

Therefore, the sequence $\{x_n\}$ is bounded and consequently, $\{w_n\}$ and $\{z_n\}$ are bounded too.■
This completes the proof of Lemma 4.5.

Lemma 4.6: For $q \in \Gamma$, the sequences $\{w_n\}, \{z_n\}$, the following inequality holds:

$$\alpha_n(1-\beta_n)\frac{2-\eta}{\eta}\|w_n-z_n\|^2 \le \|x_n-q\|^2-\|x_{n+1}-q\|^2+\beta_n M_3$$

For some $M_0 > 0$.

Proof: Let $q \in \Gamma$, we compute as follows:

$$\begin{aligned}
\|x_{n+1}-q\|^2 &= \|(1-\alpha_n-\beta_n)x_n+\alpha_n z_n-q\|^2 \\
&= \|(1-\alpha_n-\beta_n)(x_n-q)+\alpha_n(z_n-q)-\beta_n q\|^2 \\
&= \|(1-\alpha_n-\beta_n)(x_n-q)+\alpha_n(z_n-q)\|^2 \\
&\quad -2\beta_n\langle(1-\alpha_n-\beta_n)(x_n-q)+\alpha_n(z_n-q), q\rangle \\
&\quad +\beta_{n_n}^2\|q\|^2
\end{aligned}$$
(4.30)

$$\begin{aligned}
&= \|(1-\alpha_n-\beta_n)(x_n-q)+\alpha_n(z_n-q)\|^2 \\
&\quad +\beta_n(\beta_n\|q\|^2-2\langle(1-\alpha_n-\beta_n)(x_n-q)+\alpha_n(z_n-q), q\rangle) \\
&\le \|(1-\alpha_n-\beta_n)(x_n-q)+\alpha_n(z_n-q)\|^2+\beta_n M_1,
\end{aligned}$$

for some $M_1 > 0$. Substituting (4.26) into (30), we obtain

$$\|x_{n+1}-q\|^2 \le (1-\alpha_n-\beta_n)(1-\beta_n)\|x_n-q\|^2+(1-\beta_n)\|z_n-q\|^2+\beta_n M_1$$
(4.31)

Combining Lemma 4.3 (see estimate 4.12) and (4.31), we get

$$\|x_{n+1}-q\|^2 \le (1-\alpha_n-\beta_n)(1-\beta_n)\|x_n-q\|^2$$
$$+\alpha_n(1-\beta_n)\left[\|w_n-q\|^2-\frac{2-\eta}{\eta}\|z_n-w_n\|^2\right]$$

$$+\beta_n M_1 \qquad (4.32)$$

Using the fact that $\{x_n\}$ is bounded and (4.24), we get

$$\|w_n-q\|^2 \le \|x_n-q\|^2+\beta_n M_2, \qquad (4.33)$$

for some $M_2 > 0$. Now, using estimate (4.33) into (4.32)

$$\begin{aligned}\|x_{n+1}-q\|^2 &\le (1-\alpha_n-\beta_n)(1-\beta_n)\|x_n-q\|^2\\ &+\alpha_n(1-\beta_n)[\|x_n-q\|^2+\beta_n M_2]\\ &-\alpha_n(1-\beta_n)\frac{2-\eta}{\eta}\|z_n-w_n\|^2+\beta_n M_1\\ &=(1-\alpha_n-\beta_n)(1-\beta_n)\|x_n-q\|^2\\ &+\alpha_n(1-\beta_n)\|x_n-q\|^2+\alpha_n(1-\beta_n)\beta_n M_2\\ &-\alpha_n(1-\beta_n)\frac{2-\eta}{\eta}\|z_n-w_n\|^2+\beta_n M_1\\ &=(1-\beta_n)^2\|x_n-q\|^2-\alpha_n(1-\beta_n)\frac{2-\eta}{\eta}\|z_n-w_n\|^2\\ &+\beta_n[\alpha_n(1-\beta_n)M_2+M_1]\\ &\le \|x_n-q\|^2-\alpha_n(1-\beta_n)\frac{2-\eta}{\eta}\|z_n-w_n\|^2\\ &+\beta_n M_3,\end{aligned} \qquad (4.34)$$

for some $M_3 > 0$. Hence, we conclude that the (4.34) further implies that

$\alpha_n(1-\beta_n)\frac{2-\eta}{\eta}\|z_n-w_n\|^2 \le \|x_n-q\|^2-\|x_{n+1}-q\|^2+\beta_n M_3,$

This completes the proof of the Lemma 4.6■.

Lemma 4.7: Let $\{y_n\}$ and $\{w_n\}$ be sequences generated by the Algorithm 3.3 under Assumptions 3.1 and 3.2. Let $\{y_{n_k}\}$ and $\{w_{n_k}\}$ be subsequences of $\{y_n\}$ and $\{w_n\}$ respectively such that $\{y_{n_k}\}$ converges weakly to a point $z \in \mathcal{H}$, if $\lim_{n\to\infty}\|w_{n_k}-y_{n_k}\|=0$, then $z \in \Gamma = VIP(C,\mathcal{A})$.

Proof:

From the Algorithm 3.3 and since $y_{n_k}=P_C(w_{n_k}-\lambda_{n_k}\mathcal{A}w_{n_k})$, using Lemma 2.3, we obtain

$$\langle w_{n_k}-\lambda_{n_k}\mathcal{A}w_{n_k}-y_{n_k}, p-y_{n_k}\rangle \le 0, \forall p \in C.$$

This implies that

$$\langle w_{n_k}-y_{n_k}, p-y_{n_k}\rangle-\lambda_{n_k}\langle \mathcal{A}w_{n_k}, p-y_{n_k}\rangle \le 0$$

$$\begin{aligned}\langle y_{n_k}-w_{n_k}, p-w_{n_k}\rangle &\le \lambda_{n_k}\langle \mathcal{A}w_{n_k}, p-y_{n_k}\rangle\\ &=\lambda_{n_k}\langle \mathcal{A}w_{n_k}, w_{n_k}-y_{n_k}\rangle+\lambda_{n_k}\langle \mathcal{A}w_{n_k}, p-\mathcal{A}w_{n_k}\rangle\end{aligned}$$

Since $\lambda_{n_k} > 0$, we have

$$\lambda_{n_k}^{-1}\langle y_{n_k} - w_{n_k}, p - y_{n_k}\rangle + \langle \mathcal{A}w_{n_k}, y_{n_k} - w_{n_k}\rangle \leq \langle \mathcal{A}w_{n_k}, p - w_{n_k}\rangle. \quad (4.35)$$

Since the subsequence $\{w_{n_k}\}$ of $\{w_n\}$ is convergent weakly to a point $z \in \mathcal{H}$. Also from the Lemma 4.5, we know that $\{w_{n_k}\}$ is bounded. The, by the Lipschitz continuity of $\mathcal{A}$, it follows that $\{\mathcal{A}w_{n_k}\}$ is bounded and $\|w_{n_k} - y_{n_k}\| \to 0$. From the remark 4.1, we know that $0 < \lambda = \lim_{n\to\infty} \lambda_{n_k}$. Thus, taking $k \to \infty$ from (4.35), we get

$$\lim_{k\to\infty} \inf\langle \mathcal{A}w_{n_k}, p - w_{n_k}\rangle \geq 0, \forall p \in C$$

Furthermore,

$$\langle \mathcal{A}y_{n_k}, p - y_{n_k}\rangle = \langle \mathcal{A}y_{n_k} - \mathcal{A}w_{n_k}, p - w_{n_k}\rangle + \langle \mathcal{A}w_{n_k}, p - w_{n_k}\rangle + \langle \mathcal{A}y_{n_k}, w_{n_k} - y_{n_k}\rangle \quad (4.36)$$

Using the fact $\lim_{n\to\infty}\|w_{n_k} - y_{n_k}\| = 0$ and $\mathcal{A}$ is a L −Lipschitz continuous, we get

$$\lim_{n\to\infty}\|\mathcal{A}w_{n_k} - \mathcal{A}y_{n_k}\| \leq \lim_{n\to\infty}\left(L\|w_{n_k} - y_{n_k}\|\right) = 0,$$

This, together with (4.35) and (4.36) implies that

$$\lim_{k\to\infty} \inf\langle \mathcal{A}y_{n_k}, p - y_{n_k}\rangle \geq 0, \forall p \in C.$$

Now, we show that $z \in \Gamma$. Choose a decreasing sequence $\{\varphi_k\}$ which is positive and tend to 0 as $k \to \infty$. For each $k \geq 1$, we denote N_k the smallest positive integer such that

$$\langle \mathcal{A}y_{n_k}, p - y_{n_k}\rangle + \varphi_k \geq 0, \forall k \geq N_k \, . \quad (4.37)$$

Since $\{\varphi_k\}$ is decreasing, clearly N_k is increasing. Also, for each $k \geq 1$, since $\{y_{N_k}\} \subset C$, we have that $\mathcal{A}y_{N_k} \neq 0$ so that y_{N_k} is not a solution of the $VIP(C, \mathcal{A})$.

Now, we set

$$\omega_{N_k} = \frac{\mathcal{A}y_{N_k}}{\|\mathcal{A}y_{N_k}\|^2},$$

such that

$$\langle \mathcal{A}y_{N_k}, \omega_{N_k}\rangle = 1 \; for \; all \; k \geq 1. \quad (4.38)$$

Combining (4.37) and (4.38), we obtain

$$\langle \mathcal{A}y_{n_k}, p - y_{n_k}\rangle + \varphi_k\langle \mathcal{A}y_{N_k}, \omega_{N_k}\rangle > 0. \quad (4.39)$$

Consequently,

$$\langle \mathcal{A}y_{n_k}, p + \varphi_k\omega_{N_k} - y_{n_k}\rangle > 0.$$

By quasi-monotonicity of the operator $\mathcal{A}$ on $\mathcal{H}$, we get

$$\langle \mathcal{A}(p + \varphi_k \omega_{N_k}), p + \varphi_k \omega_{N_k} - y_{n_k} \rangle \geq 0. \tag{4.40}$$

Thus,

$$\langle \mathcal{A}p, p - y_{n_k} \rangle \geq \langle \mathcal{A}p - \mathcal{A}(p + \varphi_k \omega_{N_k}), p + \varphi_k \omega_{N_k} - y_{n_k} \rangle - \varphi_k \langle \mathcal{A}p, \omega_{N_k} \rangle \tag{4.41}$$

Next, we show that $\varphi_k \omega_{N_k} \to 0 \; as \; k \to \infty$. To see this, using our hypothesis that $\lim_{k\to\infty} \|w_{n_k} - y_{n_k}\| = 0$, we have $\{y_{n_k}\}$ converges weakly to z. Since $\{y_{n_k}\} \subset C$ and C is closed, then $z \in C$. Suppose $\mathcal{A}z \neq 0$, if not, we obtain that z is a solution. Now, using the Assumption 3.1, we have

$$0 < \|\mathcal{A}p\| \leq \lim_{k\to\infty} \inf \|\mathcal{A}y_{n_k}\|. \tag{4.42}$$

More so, using the fact that $\{y_{n_k}\} \subset C$ and $\varphi_k \to 0 \; as \; k \to \infty$, one obtains

$$0 \leq \limsup_{k\to\infty} \|\varphi_k \omega_{N_k}\| = \limsup_{k\to\infty} \left(\frac{\varphi_k}{\|\mathcal{A}y_{n_k}\|} \right) \leq \frac{0}{\|\mathcal{A}z\|} = 0,$$

that is,

$$\lim_{k\to\infty} \|\varphi_k \omega_{N_k}\| = 0.$$

From the estimate on (4.41), we obtain

$$\langle \mathcal{A}p, p - z \rangle = \lim_{k\to\infty} \langle \mathcal{A}p, p - y_{n_k} \rangle = \lim_{k\to\infty} inf \langle \mathcal{A}p, p - y_{n_k} \rangle \geq 0.$$

Therefore $z \in \Gamma$. ■ This completes the proof of the Lemma 4.7.

The proof of the Theorem 4.2.

By the Lemma 2.4, it suffices to show that

We know that $x_{n+1} = (1 - \alpha_n - \beta_n)x_n + \alpha_n z_n = (1 - \alpha_n)x_n + \alpha_n z_n - \beta_n x_n$.

$t_n = (1 - \alpha_n)x_n + \alpha_n z_n$. Then we obtain

$$\begin{aligned}
\|t_n - q\|^2 &= \|(1 - \alpha_n)x_n + \alpha_n z_n - q\|^2 \\
&= \|(1 - \alpha_n)(x_n - q) + \alpha_n(z_n - q)\|^2 \\
&= (1 - \alpha_n)^2 \|x_n - q\|^2 + \alpha_{n_n}^2 \|z_n - q\|^2 \\
&+ 2(1 - \alpha_n)\alpha_n \langle x_n - q, z_n - q \rangle \\
&\leq (1 - \alpha_n)^2 \|x_n - q\|^2 + \alpha_{n_n}^2 \|z_n - q\|^2 \\
&+ 2(1 - \alpha_n)\alpha_n \|x_n - q\| \|z_n - q\| \\
&\leq (1 - \alpha_n)^2 \|x_n - q\|^2 + \alpha_{n_n}^2 \|z_n - q\|^2 \\
&+ (1 - \alpha_n)\alpha_n \|x_n - q\|^2 + (1 - \alpha_n)\alpha_n \|z_n - q\|^2 \\
&= (1 - \alpha_n)\|x_n - q\|^2 + \alpha_n \|z_n - q\|^2
\end{aligned}$$

$$\leq (1-\alpha_n)\|x_n - q\|^2 + \alpha_n\|w_n - q\|^2.$$

(4.43)

On the other hand, we have

$$\begin{aligned}\|w_n - q\|^2 &= \|x_n + \theta_n(x_n - x_{n-1}) - q\|^2 \\ &= \|x_n - q\|^2 + 2\alpha_n\langle x_n - q, x_n - x_{n-1}\rangle \\ &\quad +\alpha_n^2\|x_n - x_{n-1}\|^2 \\ &\leq \|x_n - q\|^2 + 2\alpha_n\|x_n - q\|\|x_n - x_{n-1}\| \\ &\leq \|x_n - q\|^2 \\ &\quad +\alpha_n\|x_n - x_{n-1}\|[2\|x_n - q\| + \alpha_n\|x_n - x_{n-1}\|] \\ &\leq \|x_n - q\|^2 + \alpha_n\|x_n - x_{n-1}\|M_4,\end{aligned}$$

(4.44)

For some $M_4 > 0$. Combining (4.43) and (4.44), we obtain

$$\|t_n - q\|^2 \leq \|x_n - q\|^2 + \alpha_n\|x_n - x_{n-1}\|M_4,$$

(4.45)

Using the fact that $t_n = (1-\alpha_n)x_n + \alpha_n z_n$, we have $x_n - t_n = \alpha_n(x_n - x_{n-1})$

$$x_{n+1} = t_n - \beta_n x_n = (1-\beta_n)t_n - \beta_n(x_n - t_n) = (1-\beta_n)t_n - \beta_n\alpha_n(x_n - z_n).$$

This implies that

$$\begin{aligned}\|x_{n+1} - q\|^2 &= \|(1-\beta_n)t_n - \beta_n\alpha_n(x_n - z_n) - q\|^2 \\ &= \|(1-\beta_n)(t_n - q) - \beta_n\alpha_n(x_n - z_n) + \beta_n q\|^2 \\ &\leq (1-\beta_n)^2\|t_n - q\|^2 \\ &\quad -2\langle\beta_n\alpha_n(x_n - z_n) + \beta_n q, x_{n+1} - q\rangle \\ &\leq (1-\beta_n)\|t_n - q\|^2 + 2\langle\beta_n\alpha_n(x_n - z_n), q - x_{n+1}\rangle \\ &\quad +2\beta_n\langle q, q - x_{n+1}\rangle\end{aligned}$$

(4.46)

Using (4.45) and (4.46), we obtain

$$\begin{aligned}\|x_{n+1} - q\|^2 &\leq (1-\beta_n)\|x_n - q\|^2 + (1-\beta_n)\beta_n\alpha_n\|x_n - x_{n-1}\|M_4 \\ &\quad +2\beta_n\alpha_n\|x_n - z_n\|\|q - x_{n+1}\| + 2\beta_n\langle q, q - x_{n+1}\rangle \\ &= (1-\beta_n)\|x_n - q\|^2\end{aligned}$$

(4.47)

$$+\beta_n\begin{bmatrix}\frac{\theta_n}{\beta_n}\|x_n - x_{n-1}\|(1-\beta_n)M_4 + 2\alpha_n\|x_n - z_n\|\|q - x_{n+1}\| \\ +2\langle q, q - x_{n+1}\rangle\end{bmatrix}$$

Now, to show that $\{\|x_n - q\|^2\}$ converges to zero, it suffices to show that

$\lim_{k\to\infty} sup\langle q, q - x_{n+1}\rangle \le 0$ for every subsequence $\left\{\|x_{n_k} - q\|^2\right\}$ of $\{\|x_n - q\|^2\}$ satisfying

$$\liminf_{k\to\infty}\left(\|x_{n_k+1} - q\| - \|x_{n_k} - q\|\right) \ge 0.$$

Suppose $\{\|x_{n_k} - q\|\}$ is a subsequence of $\{\|x_n - q\|\}$ such that

$$\liminf_{k\to\infty}\left(\|x_{n_k+1} - q\|^2 - \|x_{n_k} - q\|^2\right) \ge 0.$$

Then we obtain

$$\liminf_{k\to\infty}\left(\|x_{n_k+1} - q\|^2 - \|x_{n_k} - q\|^2\right)$$
$$= \liminf_{k\to\infty}[(\|x_{n_k+1} - q\| - \|x_{n_k} - q\|)(\|x_{n_k+1} - q\| + \|x_{n_k} - q\|)]$$
$$\ge 0. \qquad (4.48)$$

Using the Lemma 4.6, we obtain

$$\lim_{k\to\infty} sup\left[(1 - \beta_{n_k})\alpha_{n_k}\frac{2-\eta}{\eta}\|w_{n_k} - z_{n_k}\|^2\right]$$
$$\le \lim_{k\to\infty}\sup\left[\|x_{n_k} - q\|^2 - \|x_{n_k+1} - q\|^2 + \beta_{n_k}M_3\right]$$
$$\le \lim_{k\to\infty} sup\left[\|x_{n_k} - q\|^2 - \|x_{n_k+1} - q\|^2\right] + \lim_{k\to\infty}\beta_{n_k}M_3$$
$$= -\lim_{k\to\infty}\inf\left[\|x_{n_k} - q\|^2 - \|x_{n_k+1} - q\|^2\right]$$
$$\le 0.$$

This implies that

$$\lim_{n\to\infty}\|w_{n_k} - z_{n_k}\| = 0. \qquad (4.49)$$

Now, we show that

$$\lim_{n\to\infty}\|w_{n_k} - y_{n_k}\| = 0.$$

We know from the Lemma 4.4 that

$$\|w_n - y_n\|^2 \le \left[\frac{1+\mu}{(1-\mu)\eta}\right]^2\|z_n - w_n\|^2,$$

which further implies with the estimate in (4.49) that

$$0 < \|w_n - y_n\|^2 \le \left[\frac{1+\mu}{(1-\mu)\eta}\right]^2\|z_n - w_n\|^2$$

$$0 < \lim_{k\to\infty} \|w_{n_k} - y_{n_k}\| \le \lim_{k\to\infty} \left[\frac{1+\mu}{(1-\mu)\eta}\right]^2 \|z_{n_k} - w_{n_k}\|^2 = 0. \tag{4.50}$$

Therefore, we obtain that

$$\lim_{k\to\infty} \|w_{n_k} - y_{n_k}\| = 0. \tag{4.51}$$

Next, we show that

$$\lim_{k\to\infty} \|x_{n_k+1} - x_{n_k}\| = 0.$$

It follows from the Algorithm 3.3 that as $k \to \infty$

$$\|w_{n_k} - x_{n_k}\| = \theta_{n_k}\|x_{n_k} - x_{n_k-1}\| = \beta_{n_k}\frac{\theta_{n_k}}{\beta_{n_k}}\|x_{n_k} - x_{n_k-1}\| \to 0. \tag{4.52}$$

Combining (4.49) and (4.52), we obtain

$$\lim_{k\to\infty} \|x_{n_k} - z_{n_k}\| = 0. \tag{4.53}$$

Thus, using the definition of x_{n+1}, the condition on β_n (see Assumption 3.2(i)) and setting $k \to \infty$, we have

$$\|x_{n_k+1} - x_{n_k}\| \le \alpha_n\|z_{n_k} - x_{n_k}\| + \beta_{n_k}\|x_{n_k}\| \to 0$$

Since the sequence $\{x_{n_k}\}$ is bounded, it follows that there exists a subsequence $\left\{x_{n_{k_j}}\right\}$ of $\{x_{n_k}\}$ which converges weakly to some pint $z \in \mathcal{H}$, such that

$$\lim_{k\to\infty} sup\langle q, q - x_{n_k}\rangle = \lim_{j\to\infty} \langle q, q - x_{n_{k_j}}\rangle = \langle q, q - z\rangle.$$

Thus, from $x_{n_{k_j}} \rightharpoonup z$ and $\|x_{n_k} - w_{n_k}\| \longrightarrow 0$, it follows that $w_{n_{k_j}} \rightharpoonup z$. Since

$$\|w_{n_k} - y_{n_k}\| = \|w_{n_k} - P_C(w_{n_k} - \lambda_{n_k}\mathcal{A}w_{n_k})\| \to 0,$$

From the Lemma 4.7, it follows that $z \in \Gamma$. From the fact that $z = P_\Gamma 0$, we obtain

$$\lim_{k\to\infty} sup\langle q, q - x_{n_k}\rangle = \langle q, q - z\rangle \le 0.$$

Since $\|x_{n_k+1} - x_{n_k}\| \to 0$, we get

$$\lim_{k\to\infty} sup\langle q, q - x_{n_k+1}\rangle \le 0. \tag{4.54}$$

Hence, using (4.54), $\lim_{k\to\infty}\frac{\theta_n}{\beta_n}\|x_n - x_{n-1}\| = 0$. From the Lemma 2.6 and Lemma 4.6, we obtain

$$\lim_{k\to\infty} \|x_n - q\| = 0, i.e., x_n \to q.$$

This completes the proof of Theorem 4.2.

5. The following corollaries are the consequences of the Theorem 4.2.

Corollary 5.1: Let C be a nonempty close and convex subset of $\mathcal{H}$ and let $\mathcal{A}: \mathcal{H} \to \mathcal{H}$ monotone operator satisfying the condition that for any $\{x_n\} \subset C, x_n \rightharpoonup q$, we get $\|\mathcal{A}q\| \leq \liminf_{n\to\infty} \|\mathcal{A}x_n\|$. Assuming Assumptions 3.2 are satisfied, then the iterative sequence generated by the following algorithm

---

Algorithm 5.1: Given $\mu \in (0,1), \theta \in [0,1), \eta > 0$. Let $x_0, x_1 \in C$.

Iterative steps: Given the current iterate, we compute as follows:

Step 1: $\begin{cases} w_n = x_n + \theta_n(x_n - x_{n-1}), \\ y_n = P_C(w_n - \lambda_n \mathcal{A} w_n), \end{cases}$

(5.1)

If $y_n = w_n$, the stop, y_n is the solution of the VIP. Otherwise, go to step 2.

Step 2: Construct

$$d(w_n, y_n) = w_n - y_n - \lambda_n(\mathcal{A}w_n - \mathcal{A}y_n), \sigma_n = \frac{\langle w_n - y_n, d(w_n, y_n)\rangle}{\|d(w_n, y_n)\|^2},$$

and compute

$$z_n = w_n - \eta\sigma_n d(w_n, y_n).$$

Step 3: Evaluate x_{n+1} via the formula:

$$x_{n+1} = (1 - \alpha_n - \beta_n)x_n + \alpha_n z_n$$

Set n:=n+1 and return to step 1.

Then, the sequence $\{x_n\}$ strongly converges to a point $z = P_\Gamma 0$.

Remark 5.1: Kindly note that Corollary 5.1 works even when the operator $\mathcal{A}$ is pseudomonotone. Also, the corollary 5.1 equally recovers the works of in Cholamjiak et al. (2020), Tian and Xu (2021), Dong el at. (2018), Cai et al. (2021) and many more.

6.Numerical Example

Let $\mathcal{H} = \ell_2(\mathbb{R})$ be a square summable sequence of a numbers equipped with the property

$\|x_1\|^2 + \|x_2\|^2 + \|x_3\|^2 + \cdots + \|x_n\|^2 + \cdots < +\infty.$

(6.1)

Let $\mathcal{A}: C \to C$ be defined by

$$\mathcal{A}(x) = (5 - \|x\|)x, \forall x \in C,$$

where $C = \{x \in \mathcal{H}: \|x\| \leq 3\}$ and $VIP(C, \mathcal{A}) = \{0\}$. For any $x, y \in C$, we have

$$\begin{aligned} \|\mathcal{A}x - \mathcal{A}y\| &= \|(5 - \|x\|)x - (5 - \|y\|)y\| \\ &= \|5x - \|x\|x - 5y + \|y\|y\| \\ &= \|5(x - y) - \|x\|(x - y) - y(\|y\| - \|x\|)\| \\ &\leq 5\|x - y\| + \|x\|\|x - y\| + \|y\|\|x\| - \|y\| \\ &\leq 5\|x - y\| + 3\|x - y\| + 3\|x - y\| \end{aligned}$$

$$= 11\|x - y\|.$$

(6.2)

Therefore, $\mathcal{A}$ is L −Lipschtiz continuous with $L = 1$. Thus, for $x, y \in C$ let $\langle \mathcal{A}x, y - x \rangle > 0$ such that

$$(5 - \|x\|)\langle x, y - x \rangle > 0.$$

Since $\|x\| \leq 3$ implies that

$$\langle x, y - x \rangle > 0.$$

Therefore, we obtain

$$\begin{aligned}\langle \mathcal{A}y, y - x \rangle &= (5 - \|y\|)\langle y, y - x \rangle \\ &\geq (5 - \|y\|)\langle y, y - x \rangle - (5 - \|y\|)\langle x, y - x \rangle \\ &\geq 2\|x - y\|^2 \geq 0.\end{aligned}$$

(6.3)

Hence, this shows that $\mathcal{A}$ is quasi-monotone on C. The metric projection on the set C can be computed as follows

$$P_C(x) = \begin{cases} x, if \ \|x\| \leq 3, \\ \dfrac{3x}{\|x\|}, otherwise. \end{cases}$$

7. Conclusion: An accelerated projection and contraction iterative algorithm for solving variational inequality which involved quasi-monotone operator has been investigated in the real Hilbert space. Without the prior knowledge of Lipchitz constants of the cost operator and sequentially weakly continuity assumption, and with self-adaptive steps size, we established a strong convergence result. We also incorporated an inertial term which is known to speed up the rate of convergence. Finally, we numerical example is presented. Thus, the result generalizes and extends so many others in the literature.

Reference

Cai, G., Dong, Q. L., & Peng, Y. (2021). Strong convergence theorems for solving variational inequality problems with pseudo-monotone and non-Lipschitz operators. Journal of Optimization Theory and Applications, 188, 447-472.

Censor, Y. Gibali, A. Reich, S. (2011). The subgradient extragradient method for solving variational inequalities in Hilbert space. J. Optim. Theory Appl. 148,318–335.

Censor, Y., Gibali, A., Reich, S. (2011). The subgradient extragradient method for solving variational inequalities in Hilbert space. J. Optim. Theory Appl. 148, 318–335.

Chidume, C. E.; Nnakwe, M. O., (2019). Iterative algorithms for split variational inequalities and generalized split feasibility problems, with applications. J. Nonlinear Var. Anal. 2, 127–140.

Chidume, C. E. Nnyaba, U. V. Romanus, O. M. Ezea, C. G. (2016). Convergence theorems for strictly Jpseudocontractions with application to zeros of Gamma-inverse strongly monotone maps. PanAmer. Math. J. 26 57–76.

Cholamjiak, P., Thong, D. V., & Cho, Y. J. (2020). A novel inertial projection and contraction method for solving pseudomonotone variational inequality problems. Acta Applicandae Mathematicae, 169, 217-245.

Dong, Q. L., Cho, Y. J., Zhong, L. L., & Rassias, T. M. (2018). Inertial projection and contraction algorithms for variational inequalities. Journal of Global Optimization, 70, 687-704.

Ezeora J. N. and Nnakwe M.O. (2021). Strong convergence theorems for variational inequalities
and fixed point problems in Banach spaces. CARPATHIAN J. MATH.
Volume 37 (2021), No. 3, Pages 477 - 487

Ezeora, J.N., Enyi, C.D., Nwawuru, F.O. and Ogbonna, R.C (2023). An algorithm for split equilibrium and fixed-point problems using inertial extragradient techniques. Comp. Appl. Math. 42, 103 (2023). https://doi.org/10.1007/s40314-023-02244-7.

Fichera, G. (1963). Sul problema elastostatico di Signorini con ambigue condizioni al contorno. Atti Accad. Naz. Lincei, VIII. Ser., Rend., Cl. Sci. Fis. Mat. Nat. 34, 138–142. Fichera, G. (1964). Problemi elastostatici con vincoli unilaterali: il problema di Signorini con ambigue condizioni al contorno. Atti Accad. Naz. Lincei, Mem., Cl. Sci. Fis. Mat. Nat., Sez. I, VIII. Ser. 7, 91–140.

Hadjisavvas, N., and S. Schaible. (1996). Quasimonotone variational inequalities in Banach spaces. Journal of Optimization Theory and Applications 90: 95–111.

Hartman, P. (1966). Stampacchia, G. On some non-linear elliptic differential-functional equations. Acta Math. 115,271–310.

He, B.S. (1997). A class of projection and contraction methods for monotone variational inequalities. Appl. Math. Optim. 35, 69–76.

He, B.S., Yang, Z.H. and X.M. Yuan. (2004). An approximate proximal-extragradient type method for monotone variational inequalities. Journal of Mathematical Analysis and Applications 300: 362–374.

Lions, J. L. (1967). Stampacchia, G. Variational inequalities. Comm. Pure Appl. Math. 20, 493–519

Nwawuru, F.O., Ezeora, J.N. (2023). Inertial-based extragradient algorithm for approximating a common solution of split-equilibrium problems and fixed-point problems of nonexpansive semigroups. J Inequal Appl 2023, 22. https://doi.org/10.1186/s13660-023-02923-3.

Polyak, B.T. (1964). Some methods of speeding up the convergence of iteration methods. Zh. Vychisl. Mat. Mat. Fiz. 4, 1–17.

Sun, D.F. (1996). A class of iterative methods for solving nonlinear projection equations. J. Optim. Theory Appl. 91, 123–140.

TAN, B., & LI, S. (2022). Revisiting Projection and Contraction Algorithms for Solving Variational Inequalities and Applications. Applied Set-Valued Analysis & Optimization, 4(2).

TAN, B., & LI, S. (2022). Revisiting Projection and Contraction Algorithms for Solving Variational Inequalities and Applications. Applied Set-Valued Analysis & Optimization, 4(2).

Thong, D.V., X.H. Li, Q.L. Dong, Y.J. Cho, and T.M. Rassias. (2020). A projection and contraction method with adaptive step sizes for solving bilevel pseudomonotone variational inequality problems. Optimization 2073–2096.

Tian, M., & Xu, G. (2021). Improved inertial projection and contraction method for solving pseudomonotone variational inequality problems. Journal of Inequalities and Applications, 2021(1), 1-20.

Tseng, P. (2000). A modified forward-backward splitting method for maximal monotone mappings. SIAM J. Control Optim. 38, 431–446.

Ugwunnadi, G.C., C. Izuchukwu, L.O. Jolaoso, C.C. Okeke, and K.O. Aremu. (2022). A modified inertial projection and contraction method for solving bilevel split variational inequality problems. Applied Set-Valued Analysis and Optimization 4 (1): 55–71.

Xiu, N.H., Zhang, J.Z. (2003). Some recent advances in projection-type methods for variational inequalities. J. Comput. Appl. Math. 152, 559–585.

Zegeye, H., N. Shahzad, and Y. Yao. (2015). Minimum-norm solution of variational inequality and fixed point problem in Banach spaces. Optimization 64: 453–471.

Zheng, L. (2018). A double projection algorithm for quasimonotone variational inequalities in Banach spaces. Journal of Inequalities and Applications 2018: 256.

ARABLE CROP FARMERS CLIMATE CHANGE INFORMATION ACCESSIBILITY IN SOUTH-SOUTH NIGERIA

[*1]Aroyehun, A.R., [1]Onoja, A.O. and [1]Ugwuja, V.C.

[1] University of Port Harcourt, Agricultural Economics and Agribusiness Management

***Corresponding Author: richestaro2014@gmail.com**

ABSTRACT

The quality and timely access to climate change information by farmers can be a decisive factor in how farmers cope with climate changes. Hence, this research examined the arable crop farmers' climate change information accessibility in South-South Nigeria. Multistage sampling techniques were used to select 90 arable crop farmers from three States in the study area, making 270 and 260 were retrieved for analysis. Data were collected through the use of a set of questionnaire and interview schedule. Descriptive statistics and multiple linear regression models were used for the analysis. Variance Inflating Factor (VIF) values were greater than one and within the acceptable region. The Tolerance is approximately one (1) which shows that multicollinearity does not exist. Durbin-Watson is two (2); indicates zero autocorrelation. Majority (95%) has access to information on climate change, 97% were awareness of climate change, and with 74% and 66% experienced flood and drought respectively. 84.6% of farmers received information on climate change through villagers' meetings, while 74.2% and 50% via radio and television respectively. Variables that had significant influence on climate change information accessibility of the arable crop farmers were educational level ($t = 3.290$; $p = 0.001$), farmer association ($t = -2.142$; $p = 0.033$), farming experience ($t = 2.498$; $p = 0.013$), awareness of climate change ($t = 22.974$; $p = 0.000$), radio ($t = 3.171$; $p = 0.002$), and television ($t = 2.087$; $p = 0.038$). The overall regression model ANOVA ($F = 64.811$ ($0.000 < 0.05$)) is statistically significant. The research therefore, recommends that extension agents should be increased, community-based climate change information centers should be established, mobile applications and SMS services should be developed to deliver weather forecasts to farmers directly, rural infrastructures should be improved, farmers can form associations to pool resources to access climate change information.

Keywords: Accessibility, Climate change, Information.

INTRODUCTION

Climate change consequences are associated natural tragedies which has caused huge economic loses globally; in 2018 about USD 225 billion across the world was recorded as loss (Alidu, Man, Ramli, Haris and Alhassan, 2022). About 95 per cent of these losses are as a result of prevalence of windstorms, floods, fire and drought as well as increase in sea level and increase in temperature which is directly linked to climate change put stress and burden on agricultural lands (Arora, 2019; Schmidt, Gonda and Transiskus, 2021). Climate changes further possess a global dare directly affecting human beings and their socio-economic daily activities consisting of health, livelihood, income, food security and wellbeing (Adeagbo, Ojo and Adetoro, 2021). Climate change also has a destructive upshot on the livelihoods of people, agricultural production, fresh water supply and other vital natural resources that are very essential for the survival of human beings (Alidu *et al*., 2022). Over the past three decades' climate change has contributed to agricultural production reduction globally between 1-5 percent per decade (Porter *et al*., 2014 as cited in Alidu *et al*., 2022).

Threats to agricultural production arising from changes in precipitation patterns which has resulted in increasing desertification in the Sahel region and flooding in the southern part of Nigeria (Okoro, Agwu and Anugwa, 2016)**;** To efficiently acclimatize to the whims of climate change, arable crop farmers need information on climate change; to an extent deficit in information, in itself, is a kind of vulnerability as it is simple for the void to be stuffed and brimful with vague, inaccurate and misleading information. According to Okoro *et al* (2016) information needs, if efficiently met, could enable and facilitate the user (the arable crop farmer) to make accurate decisions on any related problem associated with climate change facing arable crop productivity. Although many arable crop farmers are already coping with unstable climatic conditions, the weather conditions are becoming unpredictable, and some of the farmers' strategies may likely not suitable.

Timely and appropriate information on climate change of about three to six months prior to an adaptation initiative is a prerequisite for agricultural productivity and minimizes risk associated with climate change (World Bank 2016). Climate information involves the provision of daily, weekly, seasonal, medium and long-term provisions on temperatures and rainfall patterns, as well as wind, soil moisture and ocean conditions. The Nigerian Meteorological Agency (NIMET) is the national originator of climate change information which is provided from a network of national weather station on daily, weekly, monthly, seasonal as well as decadal timescales. This is sustained by international agencies, NGOs, community-based organizations, private organizations as well as research institutions. The climate information services are communicated via different dissemination channels such as radio, television, newspapers, mobile phone apps, online, agricultural extension agents, farmers' association meetings, village meetings. However, the potential benefits can only be achieved, if the climate information services are accessible, accurate and relevant for decision makers including arable crop farmers. Limited access of climate prediction has been reported in Sub-Saharan Africa (Vermeulen *et al*., 2011). Nigeria has scanty information on access to climate information particularly, South-South Nigeria.

Various studies have assessed the state of access and use of climate information using diverse models. For instance, Alidu *et al* (2022) used bivariate probit model to access smallholder farmers access to climate information and climate smart adaptation practices in the northern region of Ghana; Aliyu, Olawepo and Muhammad (2019) used descriptive to access climate change information for farmers in Nigeria focusing on women; Okoro *et al* (2016) also used descriptive to access climate change information needs of rural farmers in Enugu State; while Imam and Babuga (2021)reviewed extensively on utilization of climate change information sources among farmers in Nigeria. However, there appear to be no clear research done focusing on arable crop farmers' access and sources of climate change information in South-South Nigeria. Therefore, this study desired to fill this knowledge gap by examining the arable crop farmers' climate change information accessibility in South-South Nigeria.

The specific objectives are to:

i. identify the socio-economics and institutional characteristics of arable crop farmers in the study area;

ii. identify the sources of climate change information of the arable crop farmers in the study area; and

iii. determine climate change information accessibility of the arable crop farmers in the study area.

Hypothesis

The null hypothesis for the study was:

Ho i: The socio-economic and institutional characteristics of arable crop farmers do not have any significant influence on farmer's access to climate change information.

MATERIAL AND METHODS

The research was carried out in South-South territory of Nigeria. The South-South territory is characterized as the terrain consists of natural delta of the Niger River and the zone to the east and west of Nigeria. The natural boundaries of the South-South region can be distinct by its topography and hydrographic nature. South-South region northern boundaries are close to the divergence of the Niger River at Aboh, and the western and eastern boundaries are near the Benin River and the Imo River, respectively. South-South region consists of six States and they are Cross River State, Edo State, Rivers State, Delta, Akwa-Ibom State, and Bayelsa State. South-South region is typically a low-lying marshy area with dense network system of twisty rivers and creeks. The climate in the South-South region also favours the growing of cash crops such as coconut, pears, cocoa, cashew, oil palm, kolanut, gum Arabic, sesame and rubber among others. Arable crop grown in the Region include rice, cassava, maize, melon, yams, cocoyam, and sweet potatoes.

Multistage sampling procedures were used in the selection of respondents. First, three (3) States were selected using simple random technique from the six South-South States that's Akwa-Ibom, Bayelsa and Rivers State. Secondly, all the agricultural zones were selected in each

States, making twelve (12) agricultural zones selected. Thirdly, one (1) Local Government Area (LGA) was selected from each agricultural zone using simple random technique, making a total of twelve (12) LGAs in all. Fourthly, three (3) communities were selected from each LGAs using simple random technique making a total of nine (9) and eighteen (18) communities respectively from each State and thirty-six (36) communities in all. Lastly, from each community, with the help of the local extension personnel, a list of arable crop farming households was compiled and then ten (10) and five (5) arable crop farmers were selected respectively (based on the number of Agricultural Zones in the State) using simple random technique. This makes a total sample size of two hundred and seventy (270) arable crop farmers selected for the study. While 260 was retrieved for analysis. Descriptive and multiple linear regression model were used to analyze the data obtained using Statistical Package for the Social Sciences (SPSS 25.0) software, in addition multicollinearity of the variables were also examined.

Variance Inflating Factor (VIF) was used to test the multicollinearity in the models (GeeksforGeeks, 2021). VIF is expressed in regression model as;

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \cdots + \beta_k X_k \quad (1)$$

$$VIF = \frac{1}{1-R^2} \quad (2)$$

Where; $R^2 = \frac{\Sigma(y_{cal}-\bar{y})^2}{\Sigma\left(y_{given}-\bar{y}\right)^2}$ (3)

Table1: Decision Rules for Multicollinearity

VIF value	Decision/ Conclusion
VIF = 1	Not correlated (multicollinearity does not exist).
1 < VIF ≤ 5	Moderately correlated (low-level of multicollinearity exist).
VIF > 5	Highly correlated (high-level of multicollinearity exist).

The inverse of VIF is known as Tolerance and expressed as;

$$TOL = \frac{1}{VIF} = (1 - R^2) \quad (4)$$

Therefore, when R^2 is equal to zero ($R^2 = 0$), it indicates absence of existence of collinearity, then the Tolerance is high (i.e equal to 1).

Model Specification

The multiple linear regression model for climate change information accessibility as used by Okoro *et al* (2016) in accessing climate change information needs of rural farmers is expressed as;

$$Y = \beta + \alpha_1 X_1 + \alpha_2 X_2 + \alpha_3 X_3 + \cdots + \alpha_{12} X_{12} + \mu \quad (5)$$

Where: Y = knowledge on climate change issues; β = constant term; α_1- α_{12}= regression coefficients; X_1- X_{12} = independent variables; and μ = error term.

The implicit form of the regression equation is expressed as;

$$Y = \beta_0 + \alpha_1 X_1 + \alpha_2 X_2 + \alpha_3 X_3 + \alpha_4 X_4 + \cdots + \alpha_{10} X_{10} + \mu \quad (6)$$

Where;

Y = Access to climate change information (1 = if yes; 0 = otherwise)

X_1 = Age (number of years)

X_2 = Gender (1 = if male; 0 = female)

X_3 = Marital status (single =1; married = 2; widow/widower = 3; divorced = 4)

X_4 = Educational level (number of years spent in formal education)

X_5 = Household size (actual number of people living in the household)

X_6 = Farmers association (1 = if yes; 0 = otherwise)

X_7 = Farming experience (number of years)

X_8 = Extension contacts in the last one year (in number)

X_9 = Flooding of farmland (1 = if yes; 0 = otherwise)

X_{10} = Drought (1 = if yes; 0 = otherwise)

β_0 = Constant

α_1 - α_{10} = Coefficient of estimates

μ = Error term

RESULTS AND DISCUSSION

Collinearity diagnostics of multiple linear regression model used for arable crop farmers access to climate change information analysis

Table 2 shows the collinearity diagnostics of multiple linear regression model used for arable crop farmers access to climate change information analysis

Table 2: Collinearity Diagnostics of Multiple Linear Regression Model Used for Arable Crop Farmers Access to Climate Change Information Analysis

	Collinearity Statistics	
Variables	**Tolerance**	**VIF**
Age (in year)	0.458	2.184
Gender	0.917	1.091
Marital status	0.602	1.662
Educational level (in years)	0.784	1.276
Household size (in number)	0.862	1.161
Farmer association(s)	0.780	1.282
Farming experience (in years)	0.620	1.612
Extension contacted in the last one (1) year	0.807	1.240
Awareness of climate change	0.714	1.400
Flooding of farmlands	0.738	1.355
Drought	0.708	1.412
Radio	0.780	1.282
Television	0.890	1.123

Source: Field Survey, 2023

From Table 2 it could be concluded that multicollinearity does not exist; which indicates that the variables were not correlated. At most age (in year) of the arable crop farmers in the study area has low-level of multicollinearity exist of VIF value of 2.184; which indicates moderate correlation, since the VIF values were greater than one (1) and also within the acceptable region. Tolerance levels are approximately equal to one (1); this indicates absence of collinearity and Tolerance level is high. Therefore, the model is suitable to measure the data collected.

Descriptive analysis and summary statistics of arable crop farmers

Table 3 shows the descriptive statistics for the variables utilized in the analysis.

Table 3: Descriptive Analysis and Summary Statistics of Arable Crop Farmers

Variables	Mean	Std. Deviation
Access to information on climate change	0.95	0.211
Age (in year)	49.39	10.291
Gender	0.41	0.492
Marital status	2.07	0.516
Education level (in years)	7.84	5.239
Household size (in number)	6	1.882
Farmer association(s)	0.24	0.430
Farming experience (in years)	22.90	13.476
Extension contacted within one (1) year	0.26	0.441
Awareness of climate change	0.97	0.183
Flooding of farmlands	0.74	0.439
Drought	0.66	0.476

Source: Field Survey, 2023

From Table 3, majority (95%) of the arable crop farmers had access to information on climate change while just few (5%) had no access to the information on climate change. This implies that the arable crop farmers could have less impact of climate change in their arable crop farming and could adopt appropriate mitigation and/ or adaptation strategies to minimize the losses associated with climate change impacts. This finding agrees with Alidu *et al* (2022) who found out that 81.1% had access to climate information among smallholder farmers in northern region of Ghana. The mean age of the arable crop farmers is about 49 years and this indicates that farmers are within an active working age group for agricultural production. This finding agrees with Alidu *et al* (2022) who reported a mean age of farmers in northern region of Ghana to be 39 years. However, the finding controverts with Mueme, Mburu, Coulibaly and Mutune (2018) who found out the mean age of famers to be 53 years in Kenya showing that majority of the youth in kenya do not partake in agricultural production activities.

As shown in Table 3, 41% of the arable crop farmers are males while 59% are females. The dominance in female arable crop farmers in this research agrees with the finding of Nyang'au, Mohamed, Mango, Makate and Wangeci (2021) who found a large number of female famers in Kisii, Kenya, noted that this could be as a result of majority of the male farmers has migrated to urban centres for extra income as farm sizes shrank. However, it contradicts with that of Alidu *et al* (2022) who reported 77% males among smallholder farmers in northern region of Ghana. Table 3, also revealed that most arable crop farmers were married with mean of 2.07. The average years spent to acquired formal education is 7.8 years. This indicates that majority of arable crop farmers can read and write enough to keep farming operation records as well as increase accessibility to climate change information, which could lead to adoption of appropriate mitigation and/ or adaptation strategies and productivity of arable crops. This finding agrees with Rizwan, Ping, Saboor, Ahmed, Zhang, Deyi and Teng (2019) who found out that the years spent attain the level of education among farmers in Pakistan was 7.21 years.

As shown in Table 3, the mean household size is six (6). This shows that the arable crop farmers get more labour force to employ while aiming to increase crop productivity. This finding agrees with the report of Rizwan *et al* (2019) and Enimu, Onome, Okuma and Achoja (2022) who obtained a mean of seven (7) and eight (8) household sizes among crop farmers in Pakistan and Delta State Nigeria respectively. As regards farmers association, 24% belong to one or more farmers' association. This shows that most of the arable crop farmers in the study area did not belong to any farmer association. This finding does not agree with Alidu *et al* (2022) who reported that 86.3% of farmers in northern region of Ghana belong to farmers association. It has been established that farmers who belong to any group or an association gives them a type of social capital not only agricultural credit and inputs for farming but also provides them the opportunity to share vital information such as market and climate change Adeagbo *et al*., 2021). As presented in Table 3, the farming experience of the arable crop farmers is 22.9 years at average. This implies that the farming experience could contribute to the accessibility of climate change information to avert climate change negative impacts. This finding agrees with Rizwan *et al* (2019) and Enimu *et al* (2022) who found out that the mean of farming experience to be about 20.34 years and 24 years in Pakistan and Delta State Nigeria respectively. About 26% of the arable crop farmers had access or been visited by agricultural extension officers within one year. This finding is at variance with Alidu *et al* (2022) who reported 78.3% in Ghana. However, Muema *et al* (2018) opined that access to agricultural extension services by farmers is very crucial human capital that gives them information on current agricultural methods and climate change information in order to improve mitigation and/ or adaptation strategies.

The result from Table 3 indicates that majority (97%) of the arable crop farmers were aware of climate change scenario. This means that arable crop farmers in the study area were to a large extent aware of climate change. This finding agrees with Sow, Bah, Sow and Yaffa (2018) who reported about 64.7% of farmers in Kaffrine Region of Senegal that were aware of climate change. As result 74% and 66% of the arable crop farmers in the study area experienced flood and drought respectively.

Source of Information on Climate Change

The sources of information on climate change by the arable crop farmers is presented in Table 4

Table 4: Source of Information on Climate Change

Variables	Frequency*	Percentage
Radio	193	74.2
Television	130	50.0
Social groups/association	21	8.1
Fellow farmers	163	62.7
Extension workers	52	20.0
NGOs	18	6.9
Internet/Social media	47	18.1
Phone (App, Google etc)	48	18.5
Villager's meeting	220	84.6
Printed materials	16	6.2

Note: * means multiple responses
Source: Field Survey, 2023.

From Table 4, majority (84.6%) of the arable crop farmers received information on climate change through villagers' meetings. This finding agrees with Okoro *et al* (2016) who found out 83.8% of farmers in Enugu State Nigeria received climate change information from friends. Furthermore, 74.2% received information on climate change via radio. This finding agrees with Okoro *et al* (2016) who reported 57.1% of farmers in Enugu State Nigeria received information on climate change through radio. About 50% of the arable crop farmers received information on climate change through television. Similarly, 62.7% of the arable crop farmers received information on climate change from fellow farmers. This high percentage in receiving information through villagers meeting could be as a result of inadequate power supply or outright of power to those communities. However, information from radio and television were more authentic way of relating the information to the arable crop farmers, since radio and television stations relay agricultural programmes to the people. Information from social group/association, fellow farmers, phone, internet/ social media as well as from villagers meeting are not to be trusted or depend on with efficient information as this because they may not be coming from a proving and tested sources which could pose a risk to production.

Climate change information accessibility of the arable crop farmers

Accessibility of information on climate change by the arable crop farmers is presented in Table 5

Table 5: Climate change information accessibility of the arable crop farmers

	Unstandardized Coefficients		Standardized Coefficients		
Variables	**B**	**Std. Error**	**Beta**	**t**	**Sig.**
Constant	-0.098	0.056		-1.743	0.083
Age (in year)	0.001	0.001	-0.019	-0.413	0.680
Gender	0.008	0.014	0.019	0.600	0.549
Marital status	0.021	0.016	0.051	1.297	0.196
Educational level (in years)	0.005	0.001	0.113	3.290	0.001*
Household size (in number)	0.001	0.004	0.004	0.117	0.907
Farmer association(s)	-0.036	0.017	-0.074	-2.142	0.033*
Farming experience (in years)	0.002	0.001	0.096	2.498	0.013*
Extension contact within a year	0.009	0.016	0.020	0.587	0.558
Awareness of climate change	0.946	0.041	0.824	22.974	0.000*
Flooding of farmlands	-0.014	0.017	-0.030	-0.846	0.398
Drought	0.003	0.016	0.007	0.196	0.845
Radio	0.053	0.017	0.109	3.171	0.002*
Television	0.028	0.014	0.067	2.087	0.038*

Note: Model summary: R = 0.880; R^2 = 0.775; Adjusted R^2 = 0.763; Standard error of the estimate = 0.103; Durbin-Watson = 2; $p \leq 0.05$; * indicates significant at 5%.
Source: Field Survey, 2023.

Results of the multiple linear regression analysis on influence of socio-economic and institutional characteristics on climate change information accessibility of the arable crop farmers is presented in Table 5. The overall regression model shows that R which is the square root of R^2 indicates 88% correlation between the observed and predicted values of dependent variable. R^2 of 0.775 was obtained; this value indicates that 77.5% of the variance in climate change information accessibility of the arable crop farmers can be predicted from the independent variables, while adjusted R^2 accounted for 76.3% of the variance. The standard error of the estimate (0.103) indicates better fitness of the regression model to the data. The Durbin-Watson statistic is a test for autocorrelation in a regression model's output, Durbin-Watson of approximately two (2) was obtained; indicates zero autocorrelation. This Durbin-Watson result agrees with VIF and Tolerance in Table 2 establish absence multicollinearity. Standardized coefficients actually compare the variables to see which had the strongest relationship with the dependent variable, range from 0 to 1 or 0 to -1 (depend on the direction of the relationship), awareness of climate change (0.824) had the strongest relationship with access to climate change information among arable crop farmers in South-South Nigeria.

Educational level measured in number of years spent to acquire formal education ($t = 3.290$; $p = 0.001$) with coefficient of 0.005 is positively statistically significant influencing climate change information accessibility of the arable crop farmers. This implies that arable crop farmers with higher number of years in formal education could have more access to climate change information. This finding agrees with Okoro *et al* (2016) who found out that formal educational level had a significant positive influence on knowledge level of agriculture related climate change issues among farmers in Enugu State Nigeria. The higher the level of formal education, the more a farmer is likely to have access to climate change information (Tologbonse, Auta, Bidoli, Jaliya, Onu and Issa, 2010). Farmer association ($t = -2.142$; $p = 0.033$) with coefficient of -0.036 is negatively statistically significant influencing climate change information accessibility of the arable crop farmers. This negative coefficient could be as a result of most of the arable crop farmers did not belong to any farmer association in the study area, as seen in Table 3 only 24% of the arable crop farmers belong to farmers association. Hence, they could not partake in exchanging of ideas among the members on climate change information. This finding is at variance with Okoro *et al* (2016) who obtained a positive coefficient and indicated that most farmers belong to one or more farmer's association or social groups where they exchanged ideas among the members on climate change issues.

Farming experience ($t = 2.498$; $p = 0.013$) with coefficient of 0.002 is positively statistically significant influencing climate change information accessibility of the arable crop farmers. This implies that majority of arable crop farmers were aware of climate change which could increase the rate of climate change information accessibility. While awareness of climate change ($t = 22.974$; $p = 0.000$) with coefficient of 0.946 is positively statistically significant influencing climate change information accessibility of the arable crop farmers. This finding agree with Imam and Babuga (2021) who noted that high rate of climate change awareness is more evident with farmers with over 40 years of farming experience.

Radio ($t = 3.171$; $p = 0.002$) with coefficient of 0.053 is positively statistically significant influencing climate change information accessibility of the arable crop farmers. Television ($t = 2.087$; $p = 0.038$) with coefficient of 0.028 is positively statistically significant influencing climate change information accessibility of the arable crop farmers. This implies that access to radio and television by the arable crop farmers increases climate change information accessibility.

Analysis Of Variance (ANOVA) of Socio-economic and Institutional Characteristics of Arable Crop Farmers and Climate Change Information Accessibility

The Analysis of Variance (ANOVA) of socio-economic and institutional characteristics of arable crop farmers and climate change information accessibility is presented in Table 6

Table 6: Result of Analysis of Variance (ANOVA) on Socio-Economic and Institutional Characteristics of Arable Crop Farmers and Climate Change Information Accessibility

	Sum of Squares	df	Mean Square	F	Sig.
Regression	8.866	13	0.682	64.811	0.000
Residual	2.578	245	0.011		
Total	11.444	258			

Source: Field Survey, 2023.

Table 6 shows the result of ANOVA of arable crop farmers' access to climate change information. From the result, the F-value is 64.811 is statistically significant at 5%, the p-value of 0.000 is less than the alpha level of 0.05 (0.000 < 0.05). This implies that, the group of independent variables shows a statistically significant relationship with the dependent variable (access to information on climate change). This finding agrees with Okoro *et al* (2016) who reported that the overall regression model was significant (F = 7.189; p ≤0.05) among farmers in accessing climate change information in Enugu State Nigeria.

CONCLUSION

The research examined the determinants of arable crop farmers' climate change information accessibility in south-south Nigeria. The result Variance Inflating Factor (VIF) concluded that multicollinearity does not exist with high Tolerance level. The research shows that there are more females' arable crop farmers than males with adequate years spent on attaining formal education which foster reading and writing, with sufficient years in farming experience. Majority of arable crop farmers did not belong to any farmers association. Majority of the arable crop farmers received information on climate change through villagers' meetings, radio and television. Multiple linear regression analysis result shows that educational level, farmer association, farming experience, awareness of climate change, radio and television increase the probability of arable crop farmers' accessibility to climate information. ANOVA result indicates that the group of independent variables shows a statistically significant relationship with the access to information on climate change.

RECOMMENDATIONS

From the findings, the following recommendations were made:

i. Arable crop farmers were aware of the existence of extension agents and their mandate to disseminate ready-made information to farmers generally, but arable crop farmers have less access to such information. Hence, there is need to increase the number of extension agents;

ii. Develop mobile applications and SMS services that could deliver weather forecasts, climate tips and farming advice directly to the arable crop farmers phones directly, this would increase the coverage of climate change information accessibility. In addition, there radio and television programmes collaboration with local radio and television stations to broadcast climate-related information and farming tips since they can reach a wide audience;

iii. Government and NGOs could establish community-based climate change information centers where arable crop farmers can access data receive training and exchange knowledge with experts. Furthermore, there should be improvement in rural infrastructures such as electrification, roads and transportation, to enhance the accessibility of climate change information to rural dwellers; and

iv. Farmers should be encouraged to form farmer associations or cooperatives that can pool resources to access climate change information and implement climate-resilient farming techniques collectively. Involvement of farmers in the designing and implementation of climate information systems to ensure they meet local needs are culturally appropriate.

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REFERENCES

Adeagbo, O., Ojo, T. and Adetoro, A. (2021). Understanding the determinants of climate change adaptation strategies among smallholder maize farmers in South-west, Nigeria. *Heliyon, 7*(2), e06231. DOI:10.1016/j.heliyon.2021.e06231

Alidu, A.-F., Man, N., Ramli, N.N., Haris, N.B.M. and Alhassan. A. (2022). Smallholder farmers access to climate information and climate smart adaptation practices in the northern region of Ghana. *Heliyon, 8*, 1-9. https://doi.org/10.1016/j.heliyon.2022.e09513

Aliyu, H.K., Olawepo, R.A. and Muhammad, S. (2019). Climate change information for farmers in Nigeria: what challenges do women face? *Earth and Environmental Science, 399*, 1-7. doi:10.1088/1755-1315/399/1/012001

Arora, N.K. (2019). Impact of climate change on agriculture production and its sustainable solutions. *Environmental Sustainability*, 2, 95-96. https://doi.org/10.1007/s42398-019-00078-w

Enimu, S., Onome, E.G., Okuma, O.L. and Achoja, F.O. (2022). Choice of climate change adaptation strategies used by food crop farmers in Delta State, Nigeria: The multinomial logistic regression approach. *Nigerian Agricultural Policy Research Journal (NAPReJ), 10*, 143-151.

GeeksforGeeks (2021). Test of multicollinearity. Retrieved from: https://www.geeksforgeeks.org/test-of-multicollinearity/

Imam, M. and Babuga, U.S. (2021). Utilization of climate change information sources among farmers in Nigeria. *Direct Research Journal of Agriculture and Food Science, 9*, 144-148. DOI:https://doi.org/10.26765/DRJAFS5893722617

Muema, E., Mburu, J., Coulibaly, J. and Mutune, J. (2018). Determinants of access and utilization of seasonal climate information services among smallholder farmers in Makueni County, Kenya. Heliyon 4 (11), e00889. DOI:10.1016/j.heliyon.2018.e00889

Nyang'au, J.O., Mohamed, J.H., Mango, N., Makate, C. and Wangeci, A.N. (2021). Smallholder farmers' perception of climate change and adoption of climate smart agriculture practices in Masaba South Sub-county, Kisii, Kenya. *Heliyon, 7*(4), e06789. DOI:10.1016/j.heliyon.2021.e06789

Okoro, J. C., Agwu, A.E. and Anugwa, I.Q. (2016).Climate change information needs of rural farmers in Enugu State. *Journal of Agricultural Extension, 20*(2), 215-232. http://dx.doi.org/10.4314/jae.v20i2.16

Rizwan, M., Ping, Q., Saboor, A., Ahmed, U.I., Zhang, D., Deyi, Z. and Teng, L. (2019). Measuring rice farmers' risk perceptions and attitude: Evidence from Pakistan, Human and Ecological Risk Assessment. *An International Journal*, 1-16 DOI:10.1080/10807039.2019.1602753

Schmidt, M., Gonda, R. and Transiskus, S. (2021). Environmental degradation at Lake Urmia (Iran): Exploring the causes and their impacts on rural livelihoods. *Geojournal 86*, 2149-2163. https://doi.org/10.1007/s10708-020-10180-w

Sow, B.L., Bah, A., Sow, P. and Yaffa, S. (2018). Farmers' awareness and adaptation to climate change in Kaffrine Region of Senegal. *Journal of Environment and Earth Science, 8*(4), 51-59. Retrieved from: https://www.iiste.org/Journals/index.php/JEES/article/view/41911/43156

Tologbonse, E.B., Auta, S.J., Bidoli, T.D., Jaliya, M.M., Onu, R.O. and Issa, F.O. (2010). Farmers' perception of the effects of climate change and coping strategies in three agro-ecological zones of Nigeria. *Journal of Agricultural Extension, 14*(1), 125. DOI:**10.4314/jae.v14i1.64080**

Vermeulen, J., Aggarwal, P.K., Ainslie, A., Angelone, C., Campbell, B.M., Challinor, A.J. and Wollenberg, E. (2011). Options for support to agriculture and food security under climate change. *Environmental Science and Policy*, 1-9. https://doi.org/10.1016/j.envsci.2011.09.003

World Bank. (2016). Climate information services providers in Kenya. Agriculture global practice technical assistance paper. World Bank group report number 103186-KE; Washington, DC, USA. Retrieved from: https://documents1.worldbank.org/curated/fr/706021467995075539/pdf/103186-REVISED-PUBLIC-AG-GP-TAP-CIS-Providers-in-Kenya-WEB-02292016.pd

Result

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.	Collinearity Statistics Tolerance	Collinearity Statistics VIF
1	(Constant)	-.098	.056		-1.743	.083		
	Age (in year)	.001	.001	-.019	-.413	.680	.458	2.184
	Gender	.008	.014	.019	.600	.549	.917	1.091
	Marital status	.021	.016	.051	1.297	.196	.602	1.662
	Education level (in years)	.005	.001	.113	3.290	.001	.784	1.276
	Household size (in number)	.001	.004	.004	.117	.907	.862	1.161
	Farmer association(s)	-.036	.017	-.074	-2.142	.033	.780	1.282
	Farming experience (in years)	.002	.001	.096	2.498	.013	.620	1.612
	Extension contacted in the last one (1) year	.009	.016	.020	.587	.558	.807	1.240
	Awareness of climate change	.946	.041	.824	22.974	.000	.714	1.400
	Flooding of farmlands	-.014	.017	-.030	-.846	.398	.738	1.355
	Drought	.003	.016	.007	.196	.845	.708	1.412
	Radio	.053	.017	.109	3.171	.002	.780	1.282
	Television	.028	.014	.067	2.087	.038	.890	1.123

a. Dependent Variable: Access to information on climate change

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.880[a]	.775	.763	.103	1.969

a. Predictors: (Constant), Television, Gender of the respondent, Household size (in number), Agricultural extension contacted in the last one (1) year, Radio, Flooding of farmlands, Farming experience in crop farming (in years), Marital status, Farmer association(s), Years spent to attain the level of education (in years), Awareness of climate changing, Drought, Age of the respondent (in year)
b. Dependent Variable: Access to information on climate change

EFFECT OF HIGH CONCENTRATION OF TRACE METALS ON PUBLIC HEALTH IN UTURU AREA, LOWER BENUE TROUGH, NIGERIA.

Okonkwor, S. O. and Ukaegbu, V. U.

Department of Geology, University of Port Harcourt,

P.M.B 5323 Port Harcourt, Rivers State, Nigeria.

ABSTRACT

Geochemical analyses were carried out on samples obtained from Uturu, Lower Benue Trough of Nigeria, to study the effect of trace metals concentrations, particularly the toxic metals. Five rock samples, five soil samples, five native chicken samples, five samples of vegetables (okro) and four water samples, were analyzed to determine their trace metal concentration and toxicity. The samples obtained were evaluated with X- Ray Fluorescence (XRF) method. Results from the study revealed that the mean concentrations of trace metals in the samples decreased from the following; Rock samples decreased from Zn (300ppm) to Ni (20ppm). Native chicken samples decreased from Cd (440ppm) to As (20ppm). Vegetable (okro) samples decreased from Cd (400ppm) to As (20ppm). Soil samples decreased from Zn (300ppm) to As (40ppm). Water samples recorded excessive pollution in Cd (0.01ppm). Cd, Pb, As, Cu, Zn, Se, Ni, are the most toxic trace metals found in the study area which recorded excessive pollution in all samples. The inhabitants of the study area are at risk of respiratory tract diseases, hair and skin discoloration, carcinogenic diseases, kidney disease, central nervous system disorder, renal dysfunction, loss of vision and skin irritation. The outcome of this study has provided a database for intervention endeavors for health practitioners to comprehensively monitor and control health issues arising from geologic and mining processes in Uturu area of the Lower Benue Trough.

Keywords: Trace Metals, XRF spectrometer, Lower Benue Trough.

INTRODUCTION

Trace metals exist in natural and disturbed environments in small amounts. They occur at a very low concentration and are expressed in parts per million. Trace metals present in magma are usually released into the environment during igneous activities. Toxic trace metals are harmful when consumed at sufficiently high levels for long period of time. Trace metals can be taken in by animals through diet and environmental exposure, and in plants by absorption of nutrients from the soil where they grow. The ingestion of these trace metals and exposure to excessive quantities can be toxic to the environment and public health. The pathways through which trace metals in the environment affect human health include: Air (inhalation), Absorption, Drinking water and Food cycles. Trace metals induced effects include; Carcinogenic, Teratogenic and Mutagenic. The study area lies within latitudes $07^0\,25^/\,0^{//}$ N to $07^0\,25^/\,25^{//}$ N and longitude $05^0\,52^/\,10^{//}$ E to $05^0\,52^/\,35^{//}$ E, in the northern part of Abia State, Southern Benue Trough, Nigeria. The study will provide a data base for intervention endeavors for health practitioners to comprehensively monitor and control health issues arising from geologic and mining activities in Uturu area of Abia State.

GEOLOGIC SETTING

The study area consists of Ajali Formation (false-bedded sandstones) as well as Lower Coal Measures which Reyment (1965) called "Mamu" Formation. The coal-bearing part of the formations is predominantly mudstone and sandy clay (Simpson, 1955). The formation sediments were deposited during the late Tertiary-Early Cretaceous period. The false bedded sandstones consist of thick, friable, poorly sorted sandstones typically white in colour, but sometimes iron stained, often marked by repetitive banding of coarse and fine-grained layers. The sand grains, especially the longer ones are sometimes sub-angular in shape. Because of these characteristics, the formation is highly porous (Igbozurike, 1986). The Lower Coal Measures comprises mainly of coarse-grained, alternating sediment of grey sand, dark, sandy shale and carbonaceous shale, containing thin brand of impure coal in place at various horizons. Estimated thickness is 300 to 350 m (Igbozurike, 1986).

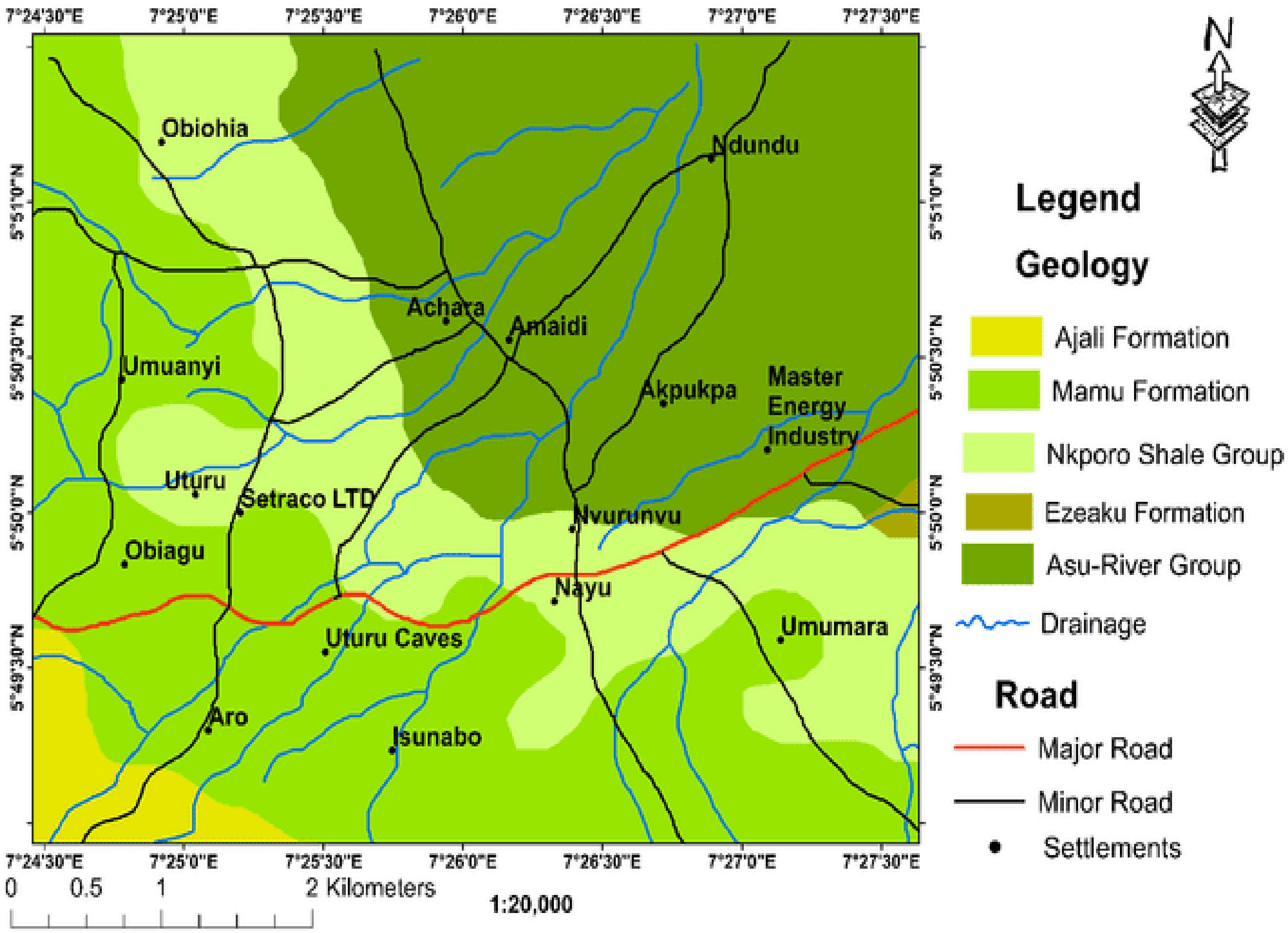

Figure 2: Geological Map of Uturu showing the study Area.

METHODOLOGY

Five samples of rocks, five samples of soil, five samples of edible vegetable (okro), five animal samples (native chicken) and four water samples were collected within the study area. The samples were obtained from mining pits, streams, and farmlands. These 24 samples were analyzed at the Centre for Dryland Agriculture, Bayero University, Kano, Nigeria, with X- Ray Fluorescence (XRF) method, to detect the following toxic trace metals in each location and their concentration level; Pb, Cr, Ni, Co, Cu, Cd, As, V, Sb, Ba, Mo, and Se.

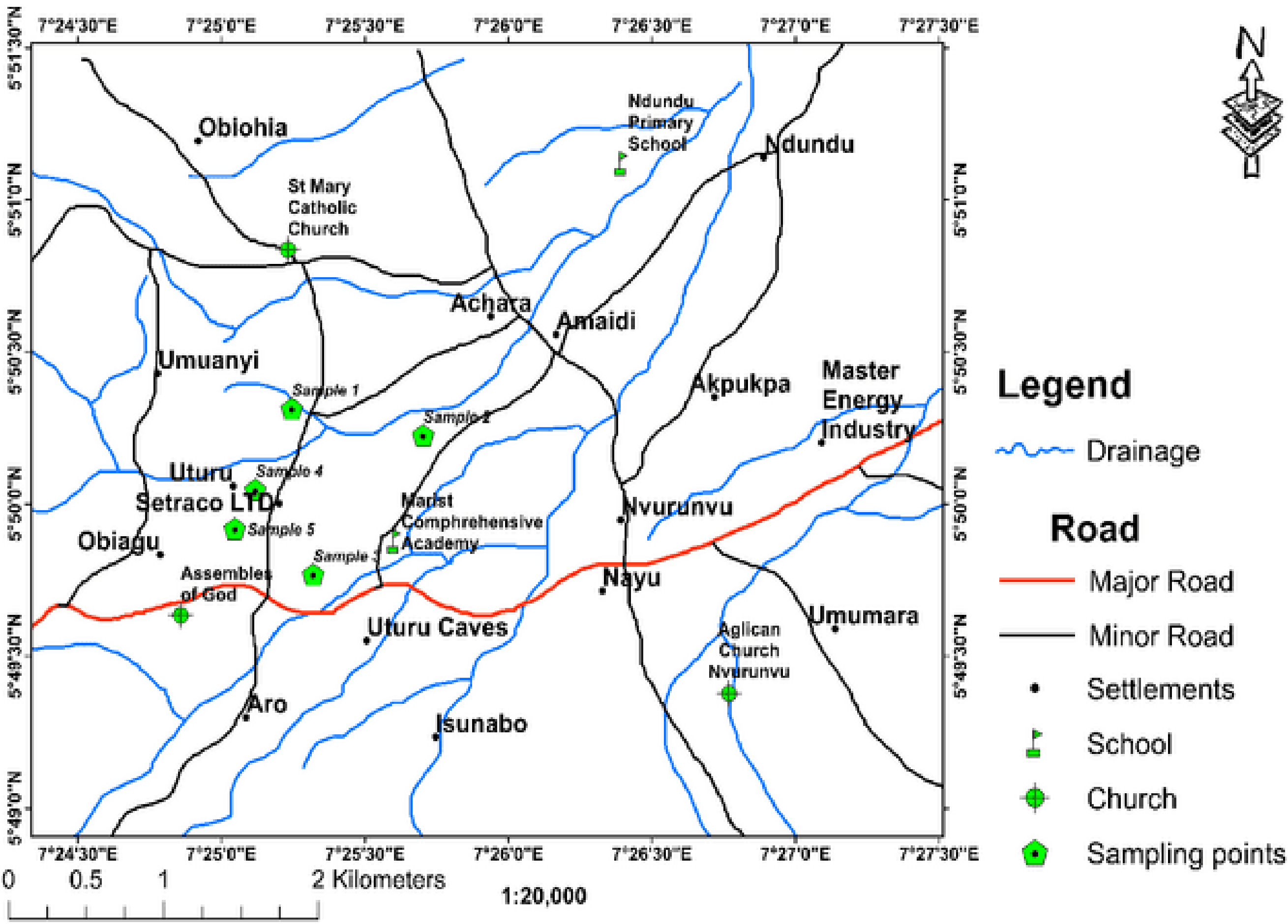

Figure 1. Map of the study area, showing the sampling points.

SAMPLING METHOD

To determine the effect and the contamination level in the area as a result of the trace metals contaminants from the Setraco quarry mines in the area; the following samples, five rock samples at the source, five soil samples, five native chicken samples (chicken offal), five samples of vegetables (Okro), and four water samples were sampled from the mine and within the environs. The sampling points were noted with the aid of a Global Positioning System (GPS) so as to detect the geographic positions.

Five rock samples were collected from the study area. They were broken with the aid of a hammer from a rock mass to serve as an example of the larger body. The rock sampling was undertaken to determine the concentration of trace metals present. The rocks are the primary source of trace metals in the study area.

Five soil samples were collected with a nylon bag and labelled appropriately for proper identification at the processing laboratory. Shovels were used to collect the soil samples and was thoroughly cleaned before usage at different sampling points. The soil samples were sun dried overtime and sieved with an aperture size of 0.7mm.

Five vegetable samples were obtained from the local harvesters via purchase from the home markets. The samples were planted proximal to the Setraco quarry site so as to evaluate the trace metals concentration present in the crops or farm produce in the area. The study would help to predict the eminent damage toxic trace metals would transmit from the source rock to the soils and to the crops that would be consumed by humans in the locality.

Four water samples were collected from within and around the Setraco quarry sites. The water sampling in the area was carried out during a sunny day under good weather condition so as to avoid rain water contamination that could alter the water concentration or dilute the water contaminates degree in the area. The water samples were collected with bottle containers, and were pre-cleaned with the sample water before collection of the actual sample of interest from different location within the quarry site. The water samples were bottled in plastic containers.

Five animal samples (native chicken) were purchased from the local residents/farmers in the study area. The animal samples were breaded within the study area so as to evaluate the trace metals concentration present in the livestock that are inhabiting within the study area.

The animal samples (native chicken offal) were oven dried, pounded, repackaged and labelled accordingly.

METHOD OF DATA ANALYSIS

The samples for study (Rock, soil, edible vegetables, and animal specimen) were pre-processed (crushed to powder, sieved, repackaged and labelled accordingly) at the engineering laboratory of the University of Port Harcourt, before it was transported to Centre for Dryland Agriculture, Bayero University, Kano, Nigeria, for X- Ray Fluorescence (XRF) analysis to determine the extent of contamination. The XRF method was used due to its, low cost of sample preparation, relative ease, strong anti-jamming ability and good working stability.

Instrument used: MY17380004 Current software: Version 1.6.0.9255

RESULTS

The mean concentration values of the Trace metals chemical composition in the rock samples are; Ni (20ppm), Zn (300ppm), Cu (80ppm), Cd (20ppm) and Ba (240ppm). Results from the study revealed that the mean concentrations of the trace metals in the rock samples decreased from Zn>Ba>Cu>Ni=Cd. Table 1 below, shows the concentrations of trace metals present in rock samples obtained from the study area, in comparison with WHO permissible limits.

Table 1: Chemical composition of toxic Trace Metals in rock samples (one, two, three, four and five)

S/No	Trace Metals	Rock sample one (ppm)	Rock sample two (ppm)	Rock sample three (ppm)	Rock sample four (ppm)	Rock sample five (ppm)	Mean Value (ppm)	WHO 2020 for Igneous rocks
1	Nickel	100	0	0	0	0	20	105
2	Zinc	400	0	300	500	300	300	111.4
3	Copper	100	0	0	100	100	80	35.7

4	Cadmium	0	0	0	100	0	20	-
5	Barium	300	0	100	600	200	240	500

Red colour means values = race metals above control standard.

Blue colour means values = Trace metals below control standard

(-) = not found

The mean concentration values of the Trace metals chemical composition in the Native chicken samples are; Cu (280ppm), Cd (440ppm), Se (200ppm), Pb (80ppm), As (20ppm), Sb (100ppm) and Ni (20ppm). The mean concentrations of the trace metals in the Native chicken samples decreased from Cd to Ni as follows; Cd>Cu>Se>Sb>Pb>As=Ni. Table 2 below, shows the concentrations of trace metals present in Native chicken samples obtained from the study area, in comparison with WHO permissible limits.

Table 2: Chemical composition of Trace Metals in Native chicken samples (one, two, three, four and five)

Serial no	Trace Metals	Chicken sample one (ppm)	Chicken sample two (ppm)	Chicken sample three (ppm)	Chicken sample four (ppm)	Chicken sample five (ppm)	Mean Value (ppm)	WHO 2020 for chicken
1	Copper	0	0	500	900	0	280	0.2
2	Cadmium	600	500	400	400	300	440	0.01
3	Selenium	200	100	300	200	200	200	0.05
4	Lead	0	100	100	0	200	80	0.05
5	Arsenic	0	0	0	100	0	20	0.2
6	Antimony	0	0	200	100	200	100	-
7	Nickel	0	0	100	0	0	20	0.25

Red colour means values = race metals above control standard.

Blue colour means values = Trace metals below control standard

(-) = not found

The mean concentration values of the Trace metals chemical composition in the vegetable (okro) samples are; Cu (80ppm), Cd (400ppm), Se (120ppm), Pb (80ppm), Mo (40ppm), Sb (60ppm), Zn (180ppm), Ni (200ppm) and As (20ppm). The mean concentrations of the trace metals in the vegetable (okro) samples decreased from Zn to Pb as follows; Cd>Ni>Zn>Se>Pb=Cu>Sb>Mo>As. Table 3 below, shows the concentrations of trace metals present in Vegetable (okro) samples obtained from the study area, in comparison with WHO permissible limits.

Table 3: Chemical composition of Trace Metals in Vegetable (okro) samples (one, two, three, four and five).

Serial no	Trace Metals	Okro sample one (ppm)	Okro sample two (ppm)	Okro sample three (ppm)	Okro sample four (ppm)	Okro sample five (ppm)	Mean Value (ppm)	IPL 2012 for veges
1	Copper	0	0	100	300	0	80	73.3
2	Cadmium	300	500	200	500	500	400	0.02
3	Selenium	200	100	100	100	100	120	0.02
4	Lead	100	0	100	100	100	80	0.3
5	Molybdenium	100	100	0	0	0	40	-
6	Antimony	100	0	100	0	100	60	-
7	Zinc	0	0	900	0	0	180	99.4

8	Nickel	0	0	900	100	0	200	10
9	Arsenic	0	0	0	0	100	20	0.5

Red colour means values = race metals above control standard.

Blue colour means values = Trace metals below control standard

(-) = not found

The mean concentration values of the Trace metals chemical composition in the soil samples are; Ni (100ppm), Zn (300ppm), Cu (100ppm), Cd (100ppm), As (40ppm) and Sb (80ppm). The mean concentrations of the trace metals in the soil samples decreased from Zn to As, as follows; Zn>Ni=Cu=Cd>Sb>As. Table 4 below, shows the concentrations of trace metals present in soil samples obtained from the study area, in comparison with WHO permissible limits.

Serial no	Trace Metals	Soil sample one (ppm)	Soil sample two (ppm)	Soil sample three (ppm)	Soil sample four (ppm)	Soil sample five (ppm)	Mean Value (ppm)	DPR 1991 for soils
1	Nickel	100	100	100	100	100	100	35
2	Zinc	400	400	100	300	300	300	50
3	Copper	100	100	100	100	100	100	36
4	Cadmium	100	100	100	100	100	100	0.8

5	Arsenic	0	100	0	100	0	40	0.15
6	Antimony	100	0	100	100	100	80	-

Table 4: Chemical composition of Trace Metals in soil samples (one, two, three, four and five)

Red colour means values = race metals above control standard.
Blue colour means values = Trace metals below control standard
(-) = not found

The mean concentration values of the Trace metals chemical composition in the water samples are; Zn (0.042ppm), Cd (0.01ppm), Ag (0.045ppm), Cu (0.052ppm), Ni (0.01ppm), As (-0.05ppm), Co (0.020ppm) and Pb (0.0005ppm). The mean concentrations of the trace metals in the water samples decreased from Cu to As, as follows; Cu>Ag>Zn>Co>Cd=Ni>Pb>As. Table 5 below, shows the concentrations of trace metals present in water samples obtained from the study area, in comparison with WHO permissible limits.

Table 5: Chemical composition of Trace Metals in water samples (one, two, three and four)

Serial no	Trace Metals	Water sample one (ppm)	Water sample two (ppm)	Water sample three (ppm)	Water sample four (ppm)	Mean Value (ppm)	WHO 2020 for water
1	Zinc	0.09	0.02	0.02	0.04	0.042	5.0

2	Cadmium	0.01	0.01	0.01	0.01	0.01	0.003
3	Silver	0.05	0.03	0.15	-0.05	0.045	-
4	Copper	0.06	0.03	0.04	0.08	0.052	2.0
5	Nickel	0.01	0.01	0.01	0.01	0.01	0.07
6	Arsenic	-0.05	-0.01	0.02	-0.01	-0.05	0.01
7	Cobalt	0.026	0.045	0.012	-0.002	0.020	0.08
8	Lead	0.002	-0.002	0.005	-0.003	0.0005	0.01

Red colour means values = Trace metals above control standard.
Blue colour means values = Trace metals below control standard
(-) = not found

Table 6: Trace metals with local and international permissible limits and Contamination/ Pollution Index (CPI)

S/No	Trace Metals	Rock Mean Values (ppm)	WHO (2020) for Igneous rocks (ppm)	CPI	Soil Mean values (ppm)	DPR (1991) for soils (ppm)	CPI	Water Mean values (ppm)	WHO 2020 for water (mg/l)	CPI	Veges. mean values (ppm)	IPL (2012) for veges. (mg/kg)	CPI	Chicken mean values (ppm)	WHO (2020) for chicken (mg/kg)	CPI
1	Nickel	20	105	V.S.P	100	35	E.P	0.01	0.07	V.S.C	200	10	E.P	20	0.25	E.P
2	Zinc	300	111.4	E.P	300	50	E.P	0.042	5.0	V.S.C	180	99.4	E.P	-	-	-
3	Copper	80	35.7	E.P	100	36	E.P	0.052	2.0	V.S.C	80	73.3	E.P	280	0.2	E.P
4	Cadmium	20	-	-	100	0.8	E.P	0.01	0.003	E.P	400	0.02	E.P	440	0.01	E.P
5	Barium	240	500	V.S.P	-	-	-	-	-	-	-	-	-	-	-	-
6	Arsenic	-	-	-	40	0.15	E.P	-0.05	0.01	V.S.C	20	0.5	E.P	20	0.2	E.P

7	Antimony	-	-	-	80	-	-	-	-	-	60	-	-	100	-	-
8	Silver	-	-	-	-	-	-	0.045	-	-	-	-	-	-	-	-
9	Cobalt	-	-	-	-	-	-	0.020	0.08	V.S.C	-	-	-	-	-	-
10	Lead	-	-	-	-	-	-	0.0005	0.01	V.S.C	80	0.3	E.P	80	0.05	E.P
11	Selenium	-	--	-	-	-	-	-	-	-	120	0.02	E.P	200	0.05	E.P

The table below shows the significant interval of contamination/pollution index

Table 7: Contamination Factor interval / Pollution index by Lacatusu (2000)

Class	C/P Value Contamination	Quality Pollution index
1	<1	Very slight contamination
2	0.10-0.25	Slight contamination
3	0.26-0.50	Moderate contamination
4	0.51-0.75	Severe contamination
5	0.76-1.00	Very Severe Contamination
6	1.10-2.00	Slight Pollution
7	2.1-4.0	Moderate Pollution
8	4.1-9.0	Severe Pollution
9	9.1-16.0	Very Severe Pollution
10	>16	Excessive Pollution

From Table 6:

V.S.C = Very Slight Contamination, S.C = Slight Contamination, M.C = Moderate Contamination, S.P = Slight Pollution,

V. Se. P= Very Severe Pollution, E.P = Excessive Pollution.

Red colour values = Trace metals above control standard.

Blue colour values = metals below control standard

(-) = not found

Below are bar charts showing the trace metals concentrations present in the samples.

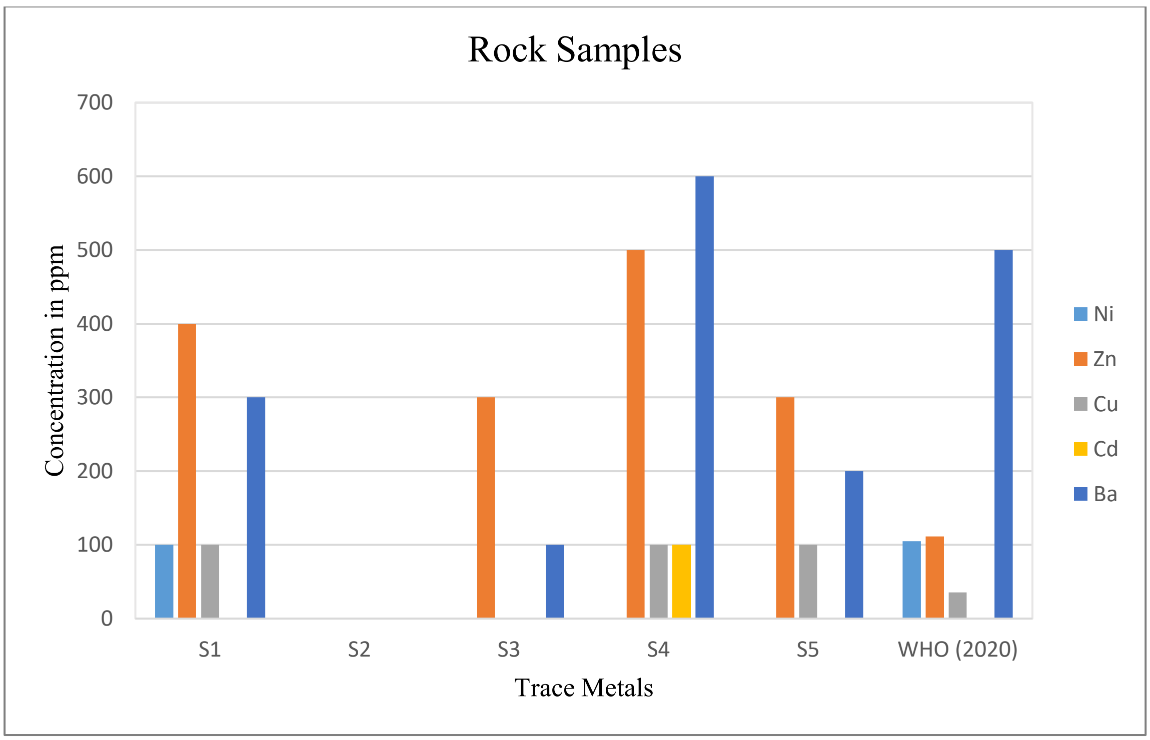

Figure 3: A Bar chart showing trace metals concentrations present in Rock samples. (S1 – S5)

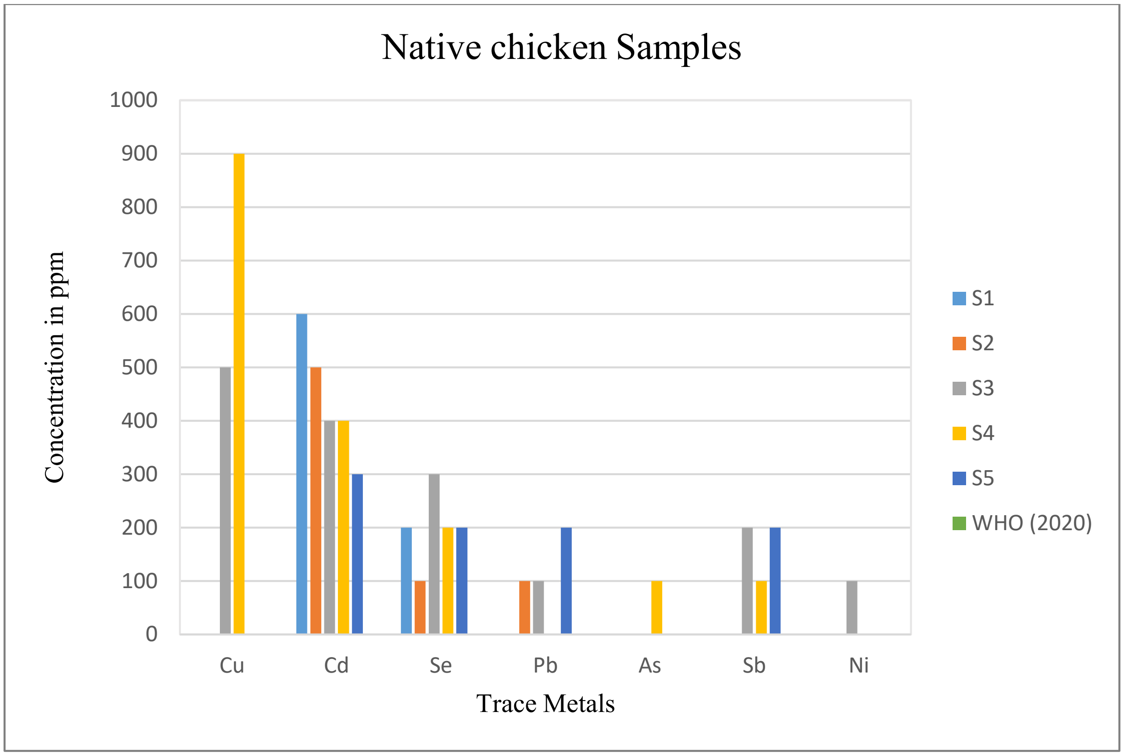

Figure 4: A Bar chart showing trace metals concentrations present in Native chicken samples. (S1 – S5).

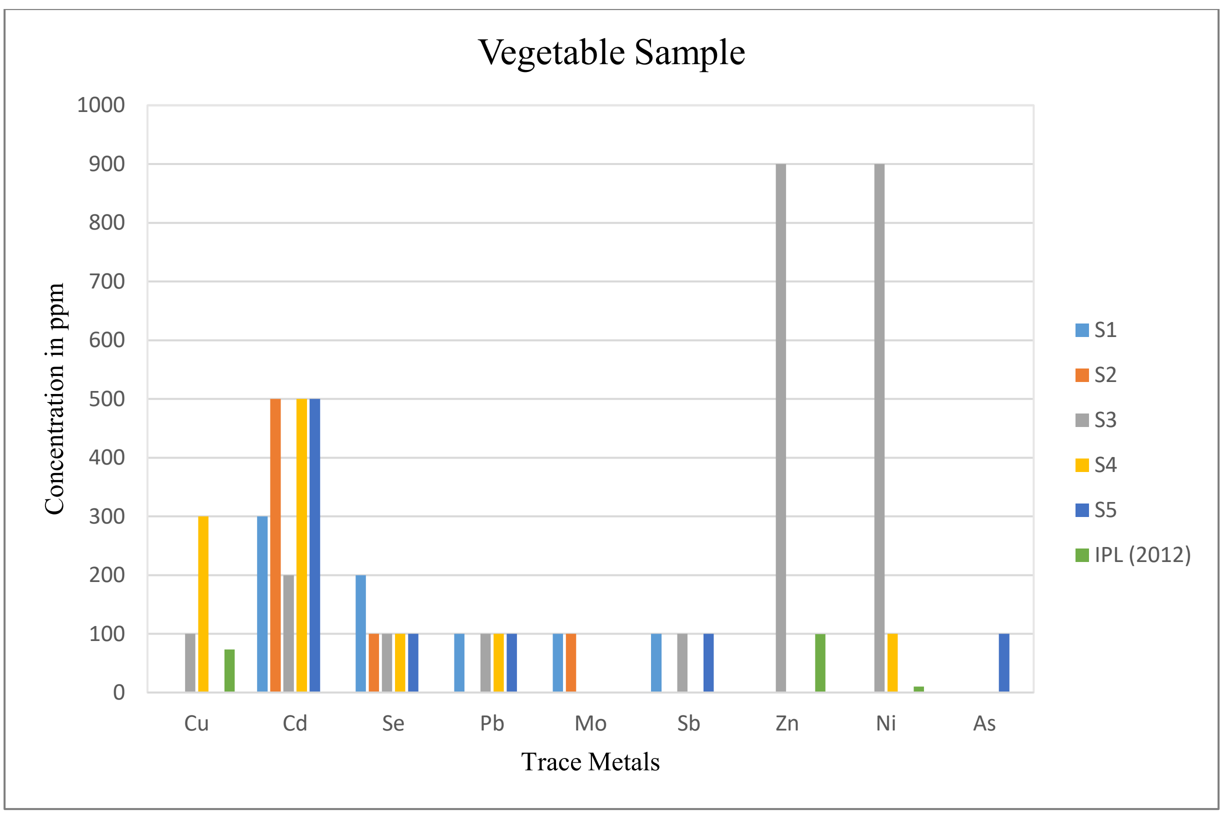

Figure 5: A Bar chart showing trace metals concentrations present in vegetable (okro) samples. (S1 -S5).

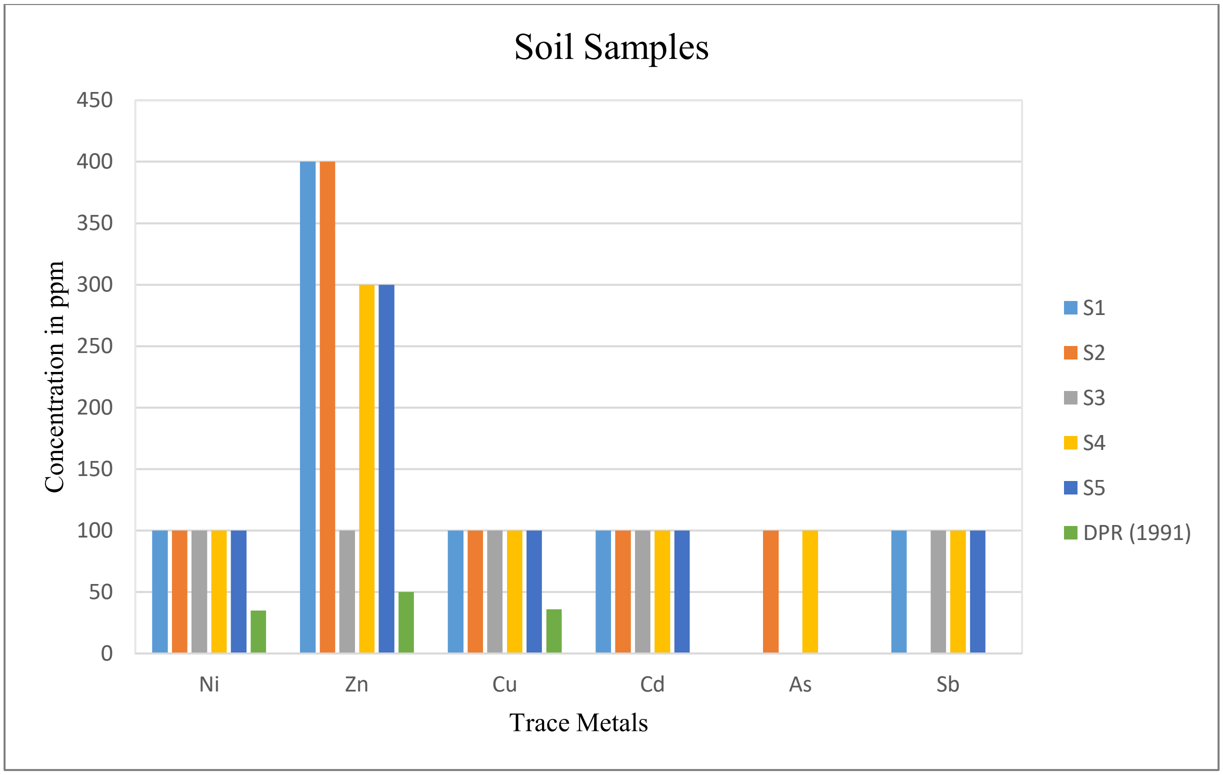

Figure 6: A Bar chart showing trace metals concentrations present in Soil samples. (S1 – S5).

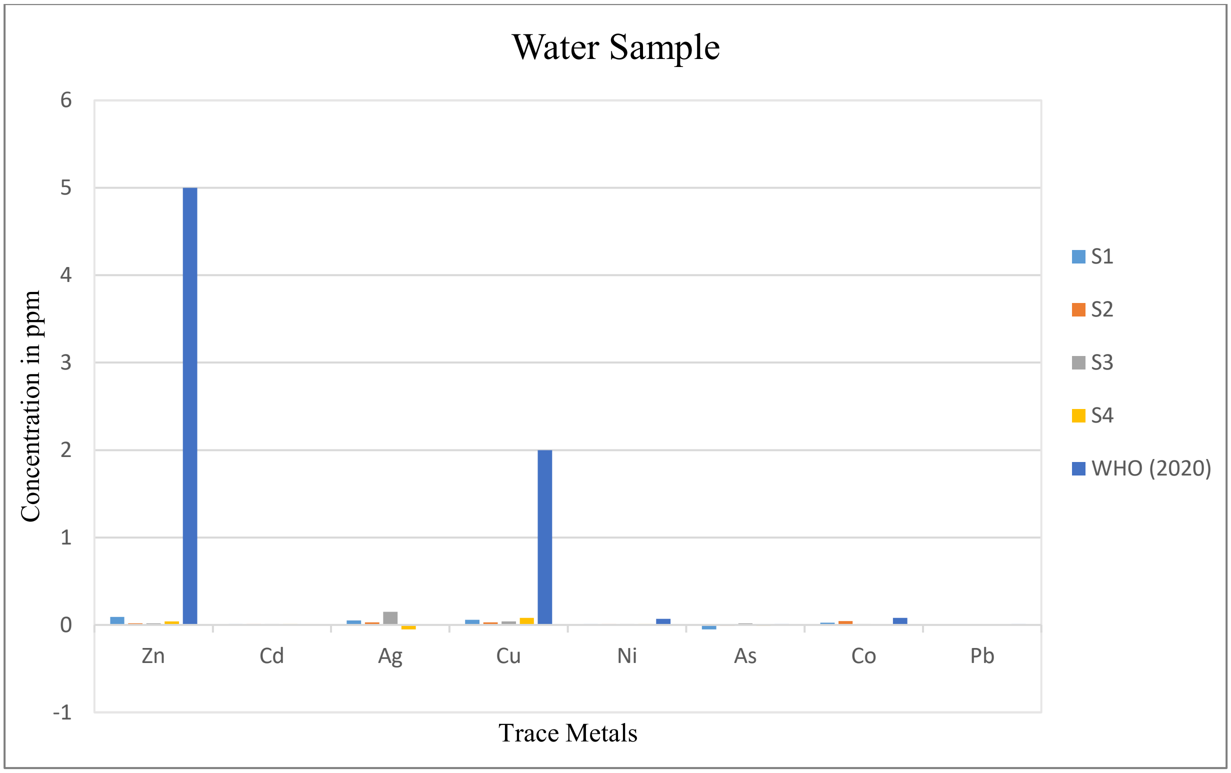

Figure 7: A Bar chart showing trace metals concentrations present in water samples. (S1 – S5)

DISCUSSION

Rock samples recorded average Zn (300ppm) and Cu (80ppm) at a toxic level of excessive pollution against the WHO (2020) limit for igneous rocks (111.4ppm) and (35.7ppm). Ni (20ppm) and Ba (240ppm) have very slight contamination quality index. Cd has no control values for comparison with results from rock sample analysis in this research.

Soil samples average of Ni (100ppm), Zn (300ppm), Cu (100ppm), Cd (100ppm), and As (40ppm) were all at a toxic level of excessive pollution range when compared with the DPR (1991) permissible limit of these trace metals in soil [Ni (35ppm), Zn (50ppm), Cu (36ppm), Cd (0.8ppm), and As (0.15ppm)].

Water samples have average concentrations of Ni (0.01ppm), Zn (0.042ppm), Cu (0.052ppm), As

(-0.05ppm), Co (0.020ppm) and Pb (0.0005ppm). It shows a quality index of very slight contamination. Cd (0.01ppm) appears to be at a toxic level of excessive pollution range when compared to the WHO (2020) permissible limit (0.003ppm). The contamination/pollution quality is from the comparison of trace metals concentrations with WHO (2020) permissible limit of these trace metals.

Vegetable samples from the study area showed excessive pollution of Ni (200ppm), Zn (180ppm), Co (80ppm), Cd (400ppm), As (20ppm), Pb (80ppm) and Se (120ppm). The International Permissible Limit (IPL) (2012) allowable limit for trace metals in vegetables are Ni (10mg/kg), Zn (99.4mg/kg), Cu (73.3mg/kg), Cd (0.02mg/kg), As (0.5mg/kg), Pb (0.3mg/kg), Se (0.02mg/kg).

Chicken samples from the study area showed excessive pollution of Ni (20ppm), Cu (280ppm), Cd (440ppm), As (20ppm), Pb (80ppm) and Se (200ppm) when compared to WHO (2020) permissible limit of trace metals in chicken offal; Ni (0.25mg/kg), Cu (0.2mg/kg), Cd (0.01mg/kg), As (0.2mg/kg), Pb (0.05mg/kg) and Se (0.05mg/kg).

From the interpretation of the result, some trace metals (Ni, Zn, Cu, Cd, As, Pb Se) will show toxicity effects on the residents of study area. The effects of Ni, Zn, Cu, Cd, As, Pb Se from excessive pollution are as follows; Zn toxicity will cause nausea, vomiting, epigastric pain, lethargy, fatigue. Ni toxicity will cause cancer of the respiratory tract, lung fibrosis, kidney and cardiovascular disease and contact dermatitis. Se-brittle nails, hair loss, mottled or decaying teeth, neurological anomalies, heart failure of which in extreme cases results in death. Cu, As, Pb, Cd toxicity effect on inhabitants of the study area is as follows: Cu - diarrhea, hemolytic anemia, cramps and kidney disease. Pb in children can lead to unhealthy brains and nervous system development, in adults kidney damage, high blood pressure, miscarriage, premature births and stillbirths in pregnant women.

Cd toxicity can cause an increased risk of lung cancer, bone and kidney damage. As toxicity can cause muscle cramps, rapid heart rate, hyperpigmentation of the skin, muscle weakness, leukopenia, skin cancer, infertility and miscarriage in women of reproductive age.

Arsenic (As) is a confirmed carcinogen and is the most significant chemical contaminant in drinking water globally. As, can also occur in an organic form. Inorganic As compounds (such as those found in water) are highly toxic while organic arsenic compounds (such as those found in seafood) are less harmful to health. The first symptoms of long-term exposure to high levels of inorganic As, (for example, through drinking water and food) are usually observed in the skin, and include pigmentation changes, skin lesions and hard patches on the palms and soles of the feet (hyperkeratosis). These occur after a minimum exposure of approximately five years and may be a precursor to skin cancer. In addition to skin cancer, long-term exposure to As, may also cause cancers of the bladder and lungs.

The International Agency for Research on Cancer (IARC) has classified arsenic and arsenic compounds as carcinogenic to humans and has also stated that arsenic in drinking-water is carcinogenic to humans. As is a natural component of the earth's crust and is widely distributed throughout the environment in the air, water and land. It is highly toxic in its inorganic form. Arsenic (As) present in soil when taken up and transported through the food chain, turns out to be toxic, affecting various life forms. Long-term exposure to low concentrations of as can lead to skin, bladder, lung, and prostate cancer. It has also been associated with cardiovascular disease and diabetes. The immediate symptoms of acute arsenic poisoning include vomiting, abdominal pain and diarrhoea. These are followed by numbness and tingling of the extremities, muscle cramping and death, in extreme cases.

CONCLUSION

The research study result shows that the chemical compositions of trace metals in the study area vary from Very Slight Contamination to Excessive Pollution range as observed from calculations for Contamination Factor (CF) evaluation. Trace metals (Ni, Zn, Se, Pb, As, Sb, Cu) in plants (vegetable), chicken and water are usually consumed either in their raw form (vegetables) or cooked (meat), which may eventually be transmitted into the body of humans in its normal, chemical or toxic state. Cd, Pb, As, Cu, Zn, Se and Ni, are the most toxic trace metals found in the study area from this research which recorded Excessive Pollution in all samples. High trace metal concentrations in the environment could foretell a great risk to human health and the environment. Heavy metal contamination has devastating effects on terrestrial ecological balance as well as diversity of aquatic organisms. Agriculture which is the mainstay of the people in the study area plays a major role in the socio-economic empowerment among inhabitants. The detection of high concentration of some metals in some samples of edible vegetation consumed by people in the study area present a health risk of these trace metals.

REFERENCE

Adamu, S., Ayuba, M., Murtala, A., & Uriah, L. A. (2014). Assessment of potentially toxic metals in soil and sediments of the Keana Brinefield in the Middle Benue Trough, North central Nigeria, 3(6-2), 77-88, 2328-5699.

Alengebawy, A., Abdelkhalek, S. T., Qureshi, S. R., & Wang, M. Q. (2021). Heavy metals and pesticides toxicity in agricultural soil and plants: Ecological risks and human health implications. *Toxics*, *9*(3), 42, 2305-6304.

Alidadi, H., Tavakoly Sany, S. B., Zarif Garaati Oftadeh, B., Mohamad, T., Shamszade, H., & Fakhari, M. (2019). Health risk assessments of arsenic and toxic heavy metal exposure in drinking water in northeast Iran. *Environmental Health and Preventive Medicine*, *24*, 1-17.

Alloway, B. J. (Ed.). (2012). Heavy metals in soils: trace metals and metalloids in soils and their bioavailability. *Springer Science & Business Media.*

Andresen, E., Peiter, E., & Küpper, H. (2018). Trace metal metabolism in plants. *Journal of Experimental Botany*, *69*(5), 909-954.

Asomugha, R. N., Udowelle, N. A., Offor, S. J., Njoku, C. J., Ofoma, I. V., Chukwuogor, C. C., & Orisakwe, O. E. (2016). Heavy metals hazards from Nigerian spices. *Roczniki Państwowego Zakładu Higieny*, *67*(3),309-314.

Banerjee, R. (2006). B12 trafficking in mammals: a case for coenzyme escort service. *ACS chemical biology*, *1*(3), 149-159.

Benson, N. U., Enyong, P. A., & Fred-Ahmadu, O. H. (2016). Trace metal contamination characteristics and health risks assessment of Commelina africana L. and Psammitic Sandflats in the Niger Delta, Nigeria. *Applied and Environmental Soil Science*, *2016, 1-14,* 8178901.

Bhattacharya, P. T., Misra, S. R., & Hussain, M. (2016). Nutritional aspects of essential trace elements in oral health and disease: an extensive review. *Scientifica*, *2016*, 5464373.

Bito, T., Misaki, T., Yabuta, Y., Ishikawa, T., Kawano, T., & Watanabe, F. (2017). Vitamin B12 deficiency results in severe oxidative stress, leading to memory retention impairment in Caenorhabditis elegans. *Redox biology*, *11*, 21-29.

Calabrese, E. J., Canada, A. T., & Sacco, C. (1985). Trace elements and public health. *Annual review of public health*, *6*(1), 131-146.

Chen, C. J., Wang, S. L., Chiou, J. M., Tseng, C. H., & Chiou, H. Y. (2011). Environmental exposure to arsenic and cardiovascular mortality in southwestern Taiwan: a reanalysis of 20-year follow-up data. *Environmental health perspectives*, 119(3), 412-416.

Chen, M., Li, D., & Xu, L. (2019). Distribution and transport of antimony in a river system impacted by mining activities. *Environmental Pollution*, 244, 731-739.

Farooq, M. A., Islam, F., Ali, B., Najeeb, U., Mao, B., Gill, R. A., ... & Zhou, W. (2016). Arsenic toxicity in plants: cellular and molecular mechanisms of its transport and metabolism. *Environmental and Experimental Botany*, *132*, 42-52. 0098-8472.

Guerra, F., Trevizam, A. R., Muraoka, T., Marcante, N. C., & Canniatti-Brazaca, S. G. (2012). Heavy metals in vegetables and potential risk for human health. *Scientia agricola*, *69*, 54-60, 3429-4486.

Hambidge, M. (2000). Human zinc deficiency. *The Journal of nutrition*, *130*(5), 1344S-1349S.

IARC Working Group on the Evaluation of Carcinogenic Risks to Humans, World Health Organization, & International Agency for Research on Cancer. (2004). *Some drinking-water disinfectants and contaminants, including arsenic* (84). IARC.

Igwe, E. O., Ede, C. O., Nnabo, P. N., & Ukpai, S. N. (2021). Impact of heavy metals dispersion on water supplies around Oshiri and Ishiagu mine districts of Southern Benue Trough, Nigeria. *Modeling Earth Systems and Environment*, *7*, 2015-2030, 2363-6211

Igwe, O., Adepehin, E. J., Iwuanyanwu, C., & Una, C. O. (2014). Risks associated with the mining of Pb–Zn minerals in some parts of the Southern Benue trough, Nigeria. *Environmental monitoring and assessment*, *186*, 3755-3765.

Igwe, O., Una, C. O., Abu, E., & Adepehin, E. J. (2017). Environmental risk assessment of lead–zinc mining: a case study of Adudu metallogenic province, middle Benue Trough, Nigeria. *Environmental monitoring and assessment*, *189*, 1-13, 1573-2959.

Izah, S. C., & Angaye, T. C. (2016). Heavy metal concentration in fishes from surface water in Nigeria: Potential sources of pollutants and mitigation measures. *Sky Journal of Biochemistry Research*, *5*(4), 31-47, 2315-8786.

Joint, F. A. O., WHO Expert Committee on Food Additives, & World Health Organization. (2011). *Safety evaluation of certain food additives and contaminants: prepared by the Seventy-third meeting of the Joint FAO/WHO Expert Committee on Food Additives (JECFA)*. World Health Organization.

Kabata-Pendias, A. (2004). Soil–plant transfer of trace elements—an environmental issue. *Geoderma*, *122*(2-4), 143-149, 0016-7061.

Kabata-Pendias, A., Adriano, D. C., & Rechcigl, J. E. (1995). Soil amendments and environmental quality. *Trace Metals*, 50.

Kavcar, P., Sofuoglu, A., & Sofuoglu, S. C. (2009). A health risk assessment for exposure to trace metals via drinking water ingestion pathway. *International journal of hygiene and environmental health*, *212*(2), 216-227, 1438-4639.

Kieliszek, M., & Błażejak, S. (2016). Current knowledge on the importance of selenium in food for living organisms: a review. *Molecules*, *21*(5), 609, 1420-3049.

Krzesłowska, M. (2011). The cell wall in plant cell response to trace metals: polysaccharide remodeling and its role in defense strategy. *Acta physiologiae plantarum*, *33*, (35-51), 1861-1664.

Lar, U. A. (2013). Trace elements and health: an environmental risk in Nigeria. *Earth Science*, *2*(3), 66-72, 10.11648.

Lar, U. A., & Sallau, A. K. (2005). Trace element geochemistry of the Keana brines field, middle Benue trough, Nigeria. *Environmental geochemistry and health*, *27*(331-339), 1573-2983.

Linhares, D. P. S., Garcia, P. V., & dos Santos Rodrigues, A. (2020). Trace elements in volcanic environments and human health effects. In *Trace Metals in the Environment-New Approaches and Recent Advances*. London, UK: IntechOpen.

Logan, T. J., & Traina, S. J. (2020). Trace metals in agricultural soils. In *Metals in groundwater* (309-347). CRC Press. 9781003069904.

Matoka, C. M., Omolo, S. O., & Odalo, J. O. (2014). Heavy metal bioaccumulation as indicators of environmental pollution and health risks. *Journal of Environmental Science, Toxicology and Food Technology*, *8*(2), 24-31, 2319-2399.

Mohamed, A. E., Rashed, M. N., & Mofty, A. (2003). Assessment of essential and toxic elements in some kinds of vegetables. *Ecotoxicology and environmental safety*, *55*(3), 251-260, 0147-6513.

Nwachukwu, I., Ukaebgu, V. U., & Egesi, N. (2019). Effects of Trace Elements Compositions of Igneous Intrusions on Public Health in Ishiagu Area of the Southern Benue trough, Southern Nigeria. *Journal of Scientific Research and Reports*, *25*(3), 1-12, 2320-0227.

Obasi, P. N., Chibuike, A., & Immaculate, N. (2023). Contamination levels and health risk assessment of heavy metals in food crops in Ishiagu area, lower Benue trough South-eastern Nigeria. *International Journal of Environmental Science and Technology*, 1-20, 1735-2630.

Odika, P. O., Anike, O. L., Onwuemesi, A. G., Odika, N. F., & Ejeckam, R. B. (2020). Assessment of environmental geochemistry of lead-zinc mining at Ishiagu area, lower Benue trough, southeastern Nigeria. *Earth Science Research*, *9*(1), 1-31, 1927-0542.

Ogah, S. P. I., Ambo, A. I., & Ukaegbu, E. E. Elemental Analysis of Water Samples from Lafia Central, Lafia East and Lafia North Areas in Nasarawa State, Nigeria. *IOSR Journal of Applied Chemistry (IOSR-JAC),* 12(9), 52-58. 2278-5736.

Oghenemavwe, L. E., & Egwede, O. B. (2022). Estimation of living stature from foot dimensions in uturu indigenes of Abia state, Nigeria. *European Journal of Medical and Health Sciences*, *4*(1), 67-71, 2593-8339.

Olade, M. A. (1975). Evolution of Nigeria's Benue Trough (Aulacogen): A tectonic model. *Geological magazine*, *112*(6), 575-583,

Oti, W. J. Toxic Metals in Soils of Mechanic Village Abakaliki, Nigeria and their Health Implications. *Idosr Journal of Scientific Research* 2(3) 43-50. 2550-794X.

Papp, L. V., Lu, J., Holmgren, A., & Khanna, K. K. (2007). From selenium to selenoproteins: synthesis, identity, and their role in human health. *Antioxidants & redox signaling*, *9*(7), 775-806.

Prasad, A. S. (2014). Zinc is an antioxidant and anti-inflammatory agent: its role in human health. *Frontiers in nutrition*, *1*, 14.

Prohaska, J. R. (2014). Copper. In Handbook of minerals as nutritional supplements. CRC Press.

Rayman, M. P. (2012). Selenium and human health. *The Lancet*, *379*(9822), 1256-1268.

Sekiya, M., Hiraishi, A., Toume, K., & Arai, M. A. (2016). Copper homeostasis and neurodegenerative disorders (Alzheimer's, prion, and Parkinson's diseases and amyotrophic lateral sclerosis). *Chemical reviews*, *106*(6), 1995-2044.

Shankar, A. H., & Prasad, A. S. (1998). Zinc and immune function: the biological basis of altered resistance to infection. *The American journal of clinical nutrition*, *68*(2), 447S-463S.

Smith, A. H., Lingas, E. O., & Rahman, M. (2000). Contamination of drinking-water by arsenic in Bangladesh: a public health emergency. *Bulletin of the world health organization*, *78*(9), 1093-1103.

Sonibare, O. O., Jacob, D. E., Ward, C. R., & Foley, S. F. (2011). Mineral and trace element composition of the Lokpanta oil shales in the Lower Benue Trough, Nigeria. *Fuel*, *90*(9), 2843-2849.

Trumbo, P., Yates, A. A., Schlicker, S., & Poos, M. (2001). Dietary reference intakes. *Journal of the American Dietetic Association*, *101*(3), 294-294.

Turnlund, J. R. (2012). Copper. In Shils M, Shike M, Ross C (eds.), Modern Nutrition in Health and Disease. 241-246.

Ukaegbu, V. U. (2008). A tectonic implication of the eruption of pyroclastics in Uturu, southern Benue Trough, southeast Nigeria. *Global Journal of Geological Sciences*, *6*(2), 123-127.

Vanoaica, L., Richaud-Patin, Y., & Dragin, N. (2017). Copper metabolism in brain and neurodegenerative diseases: a focus on neuron-glia interaction. *Frontiers in aging neuroscience.* 9, 1-11.

Williams, P. N., Raab, A., Feldmann, J., Meharg, A. A., & Zhao, F. J. (2005). Health risks of heavy metals in contaminated soils and food crops irrigated with wastewater in Beijing, China. *Environmental pollution*, 137(1), 13-20.

World Health Organisation (1996)," Trace Elements in Human Nutrition and Health". WHO, Geneva, Switzerland.

World Health Organization (2020)," Trace Elements in Human Nutrition and Health". WHO, Geneva, Switzerland.

Younes, N. R., Taha, T. M., Farid, M. E., & Farid, M. N. (2017). Health risk assessment of antimony exposure from a mining area in central Saudi Arabia. *International Journal of Environmental Research and Public Health*. 14(7). 7843-7849

Zhang, W., Graham, N. J. D., & Grant, W. D. (2019). The impact of Cu and Zn from mining on the soil microbial community and structure of mesophilic bacteria in Xinjiang, China. *Ecotoxicology and environmental safety*. 133, 153 -163.

Zhe, L., Minjuan, G., Xiaoqian, C., & Qin, L. (2019). Occupational antimony exposure and lung cancer: Systematic review and meta-analysis. *Journal of Occupational Health*, 61(1), 21 – 30.

Classification of Coal Mines in Southern Benue Trough, Nigeria using Geochemical Indices

T.M. Oluyemi[1,2*], A.C. Tse[3], and H.O. Nwankwoala[4]

[1]Department of Geology, University of Port Harcourt, Rivers State. Nigeria.
[2]Department of Geology, Federal University Oye-Ekiti, Ekiti State Nigeria
[3]Department of Geosciences, University of Namibia.
[4]Department of Geology, Rivers State University, Rivers State. Nigeria

***Corresponding author:** temmytee3@gmail.com**;** +234(0)803-542-4334

Abstract

Mine classification of three coal mines namely Afuze, Odagbo and Owukpa Coal Mines in Southern Benue Trough has been carried out using geochemical indices. A total of 38 water samples from mine tunnels, pits and adjoining steams were utilized in the study. Geochemical indices were analysed following the standard methods described by APHA (1995). The results showed that all the geochemical indices varied significantly on the basis of sample type (stream, mine ranged between 3.24 and 6.48, 0.05 and 1730, 1.20 mg/L and 1703.0 mg/L, 1.12 mg/L and 113.1 mg/L and, 0.001 mg/L and 85.9 mg/L respectively. The mines are characterized by low pH values indicating weakly to highly acidic water. The low pH values corresponded to high acidity in the mines which peaked at 1,730. The study found a relationship between pH, acidity and heavy metal concentrations in mine water. On the basis of mine acidity, the study classified the mines into Class I (Acid Mine Drainage), Class 0 (highly concentrated and acidic mine drainage) and Class II (partially oxidized and/or neutralized) for Afuze, Odagbo and Owukpa Coal Mines respectively.

Keywords: *Low PH, Acid Mine Drainage, Mine Classification*

1. Introduction

Acid mine drainage (AMD) is a complex process that occurs within the mine environment due to the interaction of biological, physical, ecological, and chemical factors. It is formed by water, oxygen, and oxidation of iron-sulphide mineral pyrite (FeS2) (Wang et al., 2021; Lazareva et al., 2019). Akcil et al., 2006, found that most sulphide minerals oxidize to form sulphuric acid (H2SO4) and metal ions (Al3+, Fe3+). The chemical analysis of water samples collected from mine sites strongly indicates that AMD has a high content of heavy metals and low pH values ranging from strongly acidic or weakly acidic (Thisani et al., 2020; Jiao et al., 2023).

The composition of AMD from tailings, mine wastes, and mine structures is primarily a function of the mineralogy of the rock material and availability of water and oxygen. Low pH values associated with AMD control the solubility and mobility of heavy metals, making them more mobile and accessible for release into the environmental media. Coal mines generate enormous volumes of wastes, which can be highly acidic with high concentrations of heavy metals depending on the type of minerals being mined.

AMD is characterized by low pH, high concentration of heavy metals, sulphates, salinity, hardness, and strong solubility with unstable acidic chemical composition (Valente & Gomes, 2007; Jiao et al., 2023). Geochemical indices are used in defining and classifying mine water, as they have proven to be useful in mine classification. These indices are known to decrease with increasing distance away from the mine and can be mineralogical, physico-chemical, and/or ecological parameters that are characteristics of AMD environment.

Previous works on Nigeria's coal mines have focused on the general geochemistry of coal mines (Nganje et al., 2010; Hatar et al., 2013; Utom et al., 2013; Ozoko, 2015; Sikakwe et al., 2015; Momoh et al., 2017; Akpan et al., 2021). However, geochemical indices that define all mines have not been strongly considered, resulting in the lack of classification of coal mines using geochemical indices and their variability.

2. Study Area

The study was carried out in three coal mines located in three different states in Nigeria namely Afuze Coal Mine (Edo State), Owukpa Coal Mine (Benue State) and Odagbo Coal Mine (Kogi

State) which lie within the geographical coordinates of Longitudes 006^{0}01’29.1’’E and Latitudes 007^{0}01’30.7’’N, Longitudes 007^{0} 47’ to 10’ 0’’ E and Latitudes 006^{0} 25’’ to 8’ 8’’ N and Longitudes 007^{0} 43’ 30’’ to 007^{0} 44’ 0’’ E and Latitudes 007^{0} 28’ 30’’ to 007^{0} 29’’ 00’’ N respectively (Figure 1).

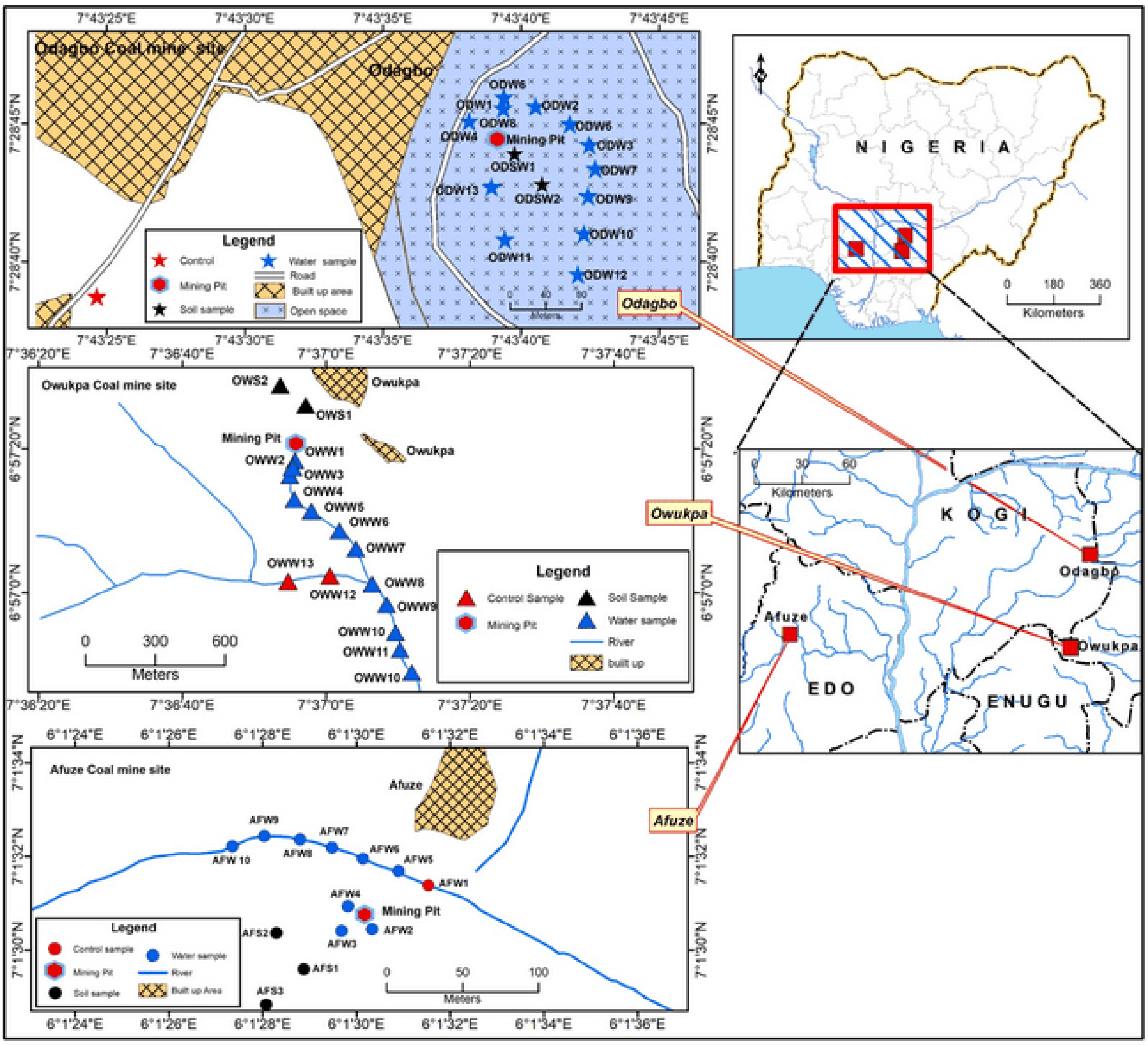

Figure 1: Location Map of the Study

2.1 Geology of the Study Area

The three coal mines fall within the Southern Benue Trough. It is bounded by the Abakaliki Anticlinorium to the northwest, Benue Trough to the northeast, the Basement Complex to the east and the Niger Delta Basin to the south (Obaje, 2009). The Southern Benue Trough, bounded by the Abakaliki Anticlinorium to the northwest, Benue Trough to the northeast, the Basement Complex to the east, and the Niger Delta Basin to the south, is home to three coal mines (Obaje, 2009). The southernmost part of the trough, Anambra Basin, is known for its abundant coal deposits, mainly found in the Mamu Formation (Ofoegbu et al., 2013). The formation is made up of interbedded sandstones, shales, and coals. The Anambra Basin is filled with the Bende Formation outcrops, the Imo Formation, the Maastrichtian-Palaeocene Nsukka Formation, and the coarse-grained false-bedded sandstones called the Ajali Formation (Nwajide, 1989). The Nkporo Formation has clays, blue dark grey shales, and occasional thin beds of sandy shale and sandstone. The Lafia Formation has continental ferruginised sandstones, red, loose sands, flaggy mudstones, and clays. The Ajali Formation overlies the Mamu Formation, which is the main aquiferous unit with thick friable, poorly sorted, cross-bedded Sandstone (Onoduku et al., 2019).

The hydrology of the Mamu Formation is crucial in the exploration and exploitation of coal deposits. The formation has both confined and unconfined conditions, with sandstone layers acting as aquifers and shale acting as aquitards. The sandstone layers within the formation acts as the aquifer, while the shale acts as aquitards, restricting water flow. The coal also within the formation are generally considered to be low permeability zones that acts as barriers to water flow (Obi *et al.,* 2008; Ofoegbu *et al.,* 2013).

3. Materials and Method

Samples utilized in the study are water samples collected from streams, mine water, pits and tunnels. A reconnaissance survey was carried out at the three locations where the water samples were collected (Plate 1). For the streams, sampling sites were selected to reflect sources of inflowing, intermediate and outflowing water. Water sampling was done with pre-labelled polyethene bottles. A total of 38 water samples (comprising 9 mine pits, 2 mine tunnels, 8 mine water, 15 streams and 4 control) were collected. The geochemical parameters used in the study were derived from the laboratory analysis. The sample analysis was carried out using the standard methods described by APHA (1995). The analysis was carried out at Stellenbosch University Laboratory in South Africa. The pH values were measured in-situ using pH digital metre.

Plate 1: Sampling and Sample Collection

4. Results

Table 1: The Mean Value and Standard Deviation (SD) of Geochemical Indices in Afuze, Odagbo and Owukpa Coal Mines

	Afuze Mine		Odagbo Mine		Owukpa Mine	
Parameters	Average Value	SD	Average Value	SD	Average Value	SD
pH	5.24	2.3	3.5	0.2	6.35	0.064
Acidity	10.46	1.98	718.2	554.0	1.019	0.426
SO_4^{2-} (mg/L)	4.32	0.31	729.2	503.6	8.412	6.774
Fe (mg/L)	4.440	3.14	76.938	74.8	19.189	8.396
Al (mg/L)	0.022	0.030	38.663	32.9	0.014	0.028

(SD= standard deviation, mg/L = milligram per litre, Fe = Iron, Al = aluminium, SO_4^{2-} = sulphate)

Table 2: The Correlation within the Geochemical Indices in the Three Coal Mines to show Relationships

Afuze			Odagbo			Owukpa		
Pair	Pearson R	L.R	Pair	Pearson R	L.R	Pair	Pearson R	L.R
pH-SO4	-0.390	WN	pH-SO4	-0.91	SN	pH-SO4	-0.20	WN
pH-Acidity	-0.450	WN	pH-Acidity	-0.93	SN	pH-Acidity	0.18	WP
pH-Fe	-0.280	WN	pH-Fe	-0.79	SN	pH-Fe	-0.25	WN
pH-Al	-0.440	WN	pH-Al	-0.90	SN	pH-Al	0.28	WP

Acidity-Fe	0.437	WP	Acidity-Fe	0.90	SP	Acidity-Fe	-0.45	WN
Acidity-Al	0.278	WP	Acidity-Al	0.91	SP	SO4-Al	-0.35	WN
SO4-Acidity	-0.275	WN	SO4-Acidity	0.99	SP	SO4-Acidity	0.24	WP
SO4-Fe	-0.011	WN	SO4-Fe	0.93	SP	SO4-Fe	-0.06	WN
SO4-Al	0.648	SP	SO4-Al	0.87	SP	SO4-Al	-0.35	WN

(LR = Linear Relationship, SP= Strongly Positive, WP = Weakly Positive, SN =Strongly Negative, WN= Weakly Negative)

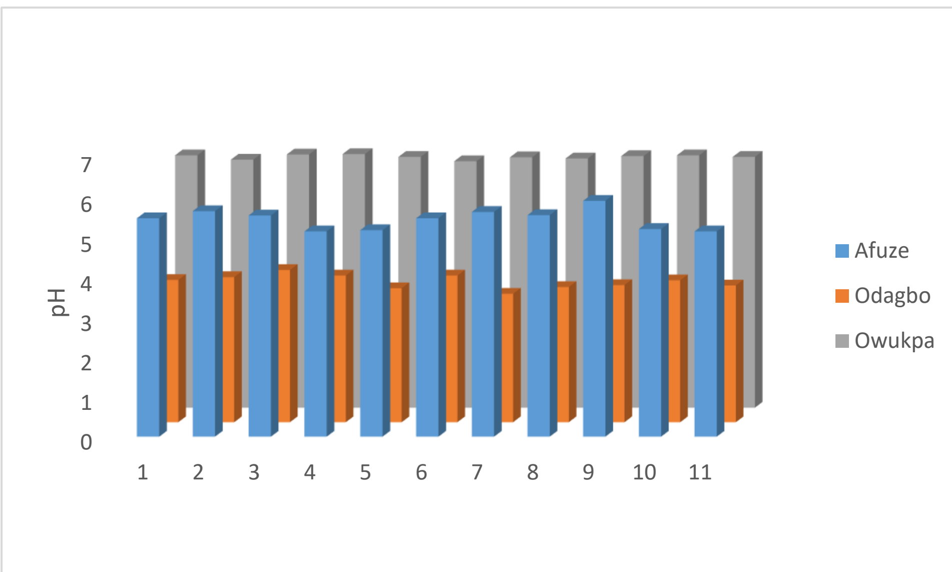

Figure 2: Comparison of the pH Values in Afuze, Odagbo and Owukpa Mines

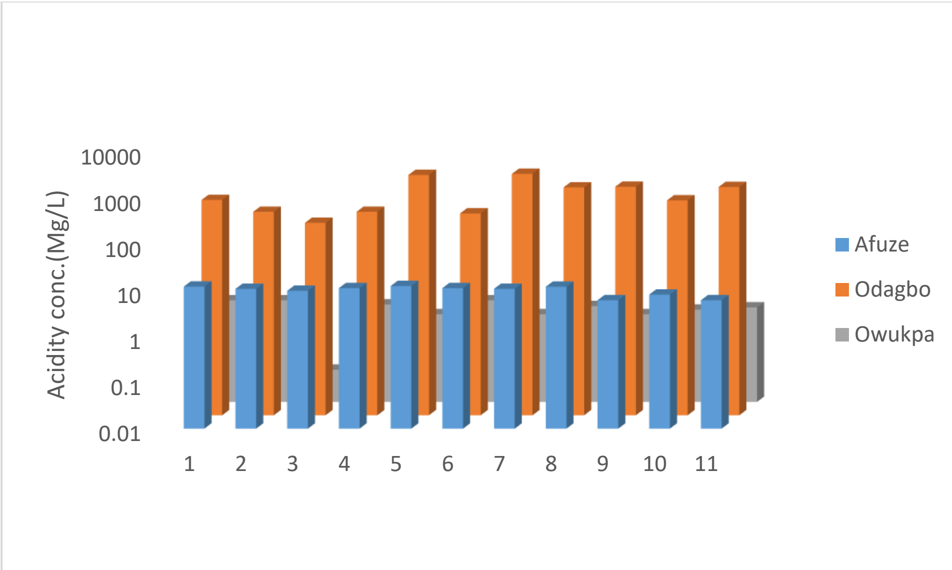

Figure 3: Comparison of the Acidity in Afuze, Odagbo and Owukpa Mines

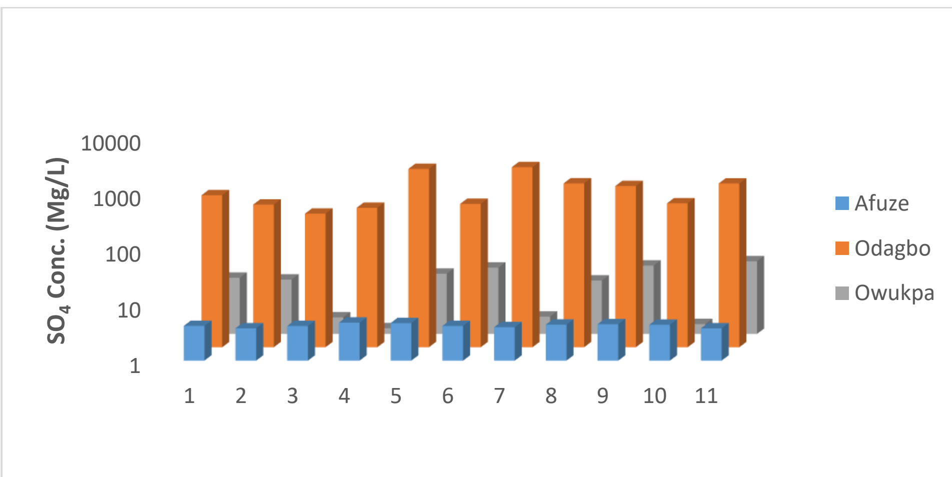

Figure 4: Comparison of the Concentrations of Sulphates in Afuze, Odagbo and Owukpa Mines

Table 3: The Classification of the Three Coal Mines

Coal Mines	Class	Geochemical Indices	Classification Framework
Afuze	Class I (AMD)	Acidity	Thisani *et al.,* (2020)

	Class II (partially oxidized and/or neutralized)	Fe	Thisani *et al.,* (2020)
	Class 6 (acidic with high Fe concentration)	Fe	Soda & Nguyen, 2023
Odagbo	Class 0 (highly concentrated and acidic mine drainage)	Acidity and Fe	Thisani *et al.,* (2020)
	Class I (AMD)	pH	Thisani *et al.,* (2020) and Hill (1968)
	Class 7 (acidic with extremely high Fe concentration)	Fe	Soda & Nguyen, 2023
Owukpa	Class II (partially oxidized and/or neutralized)	Acidity, pH and Fe	Thisani *et al.,* (2020)

	Class 6 (acidic with high Fe concentration)	Fe		Soda & Nguyen (2023)

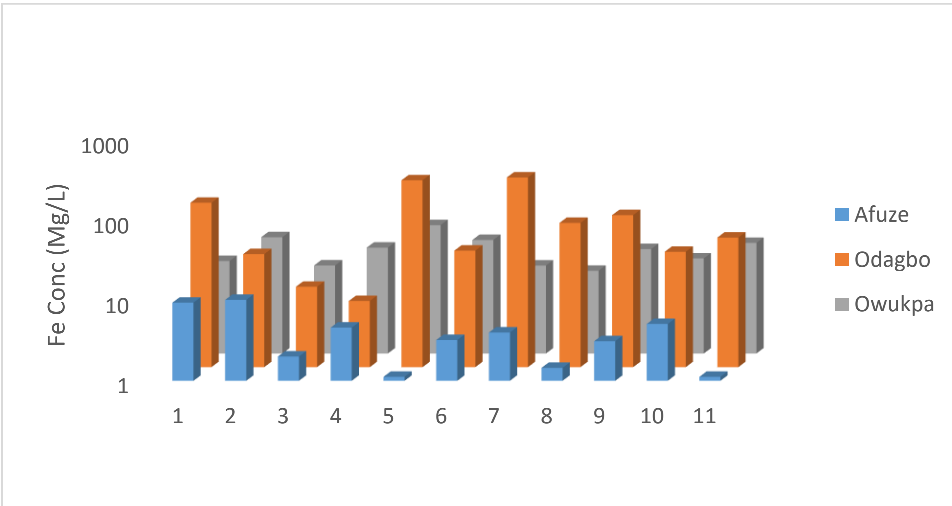

Figure 5: Comparison of the Concentrations of Iron in Afuze, Odagbo and Owukpa Mines

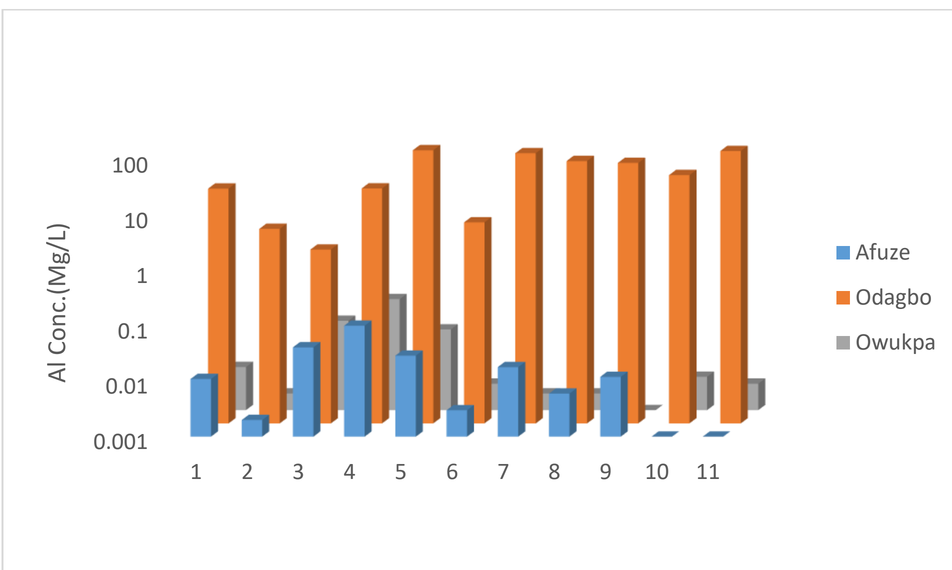

Figure 6: Comparison of the Concentrations of Aluminium in Afuze, Odagbo and Owukpa Mines

The concentrations of aluminium (Al) are low in Afuze and Owukpa Coal Mines with numerical values of 0.001 mg/L to 0.10 mg/L and 0.02 mg/L to 0.58 mg/L respectively. In Odagbo Coal Mine, the concentrations of aluminium are very high, ranging from 1.4 mg/L to as high as 85.9 mg/L (Figure 6).

4.2 Discussions

The geochemical indicators of the mine analysed are pH, acidity, sulphates, aluminium, and iron concentrations. The values were very high and varied significantly on the basis of sample type (mine water, stream, mine pit, and tunnel). The results of the geochemical indicators in the three coal mines are presented in Table 1. The geochemical indicators are correlated to determine the relationship between them (Table 2).

The pH values of the three coal mines varied significantly (Figure 2). The values ranged from 5.18 to 5.95 in Afuze Coal Mine, 3.24 to 3.84 in Odagbo Coal Mine and 6.22 to 6.48 in Owukpa Coal Mine respectively. The values indicate highly acidic to weakly acidic mine. pH is an important index of mine classification. On the basis of pH values, the mines fall within two classes of acid mine drainage classifications of Class I and Class II by Thisani (2020) Proposed Optimised Hill's Classification Framework. Owukpa Mine with a pH value of 3.24 is grouped into Class I (Acid Mine Drainage) while Odagbo with a pH value of 6.48 is grouped into Class II (Partially oxidized and/or neutralized). Low pH values have been widely reported by researchers (Nganje *et al.,* 2010; Salufu & Salufu, 2014; Ozoko *et al.,* 2015; Sikakwe *et al.,* 2015; Obiadi *et al.,* 2016). These works were carried out in different mines. The ranges of values of pH reported include 2.84 to 6.69

(Nganje *et al.,* 2010), <3.6 (Salufu & Salufu, 2014), 2.84 to 6.05 (Sikakwe *et al.,* 2015) and 2.80 to 6.08 (Obiadi *et al.,* 2016).

Acidity ranged from 9.8 to 12.48, 510 to 1730 and 0.05 to 1.60 for Afuze, Odagbo and Owukpa Coal Mines respectively. Acidity of the three mines investigated was found to vary significantly (Figure 3). The mine water acidity ranged from strongly acidic to weakly acidic. Considering the acidity and using Thisani *et al.,* (2020) classification, Owukpa Mine falls into Class II of partially oxidized and/or neutralized, Odagbo Mine falls into Class 0 of highly concentrated and acidic mine drainage while Afuze Mine falls into Class I of acid mine drainage (Table 3). Many researchers agreeably observed that high acidity is the characteristic nature of mine water (Nganje *et al.,* 2010; Sikakwe *et al.,* 2015; Akpan *et al.,* 2021; Soda & Nguyen, 2023). In a study carried out by Sikakwe *et al.,* (2015) to evaluate the acid mine drainage of Okpara Coal Mine in Enugu State, it was discovered that the mine water acidity varied significantly from acidic to very acidic. Similarly, Akpan *et al.,* (2021) characterized the water discharged from two coal mines within Enugu and reported that the water discharged from the mines was highly acidic. In a separate research to determine the concentrations of both the major and trace elements in water samples collected in and around Okpara Coal Mine in Enugu, Nganje *et al.,* (2010) showed a variation of water acidity from acidic to moderately acidic. Most AMD classifications are based on the acidity of mine water (Jiao et al., 2013, Soda & Nguyen, 2023).

The values of sulphates (SO_4^{2-}) varied between 3.80 mg/L and 4.4.72 mg/L, 249.50 mg/L and 1703.00 mg/L, and, 1.20 mg/L and 20.04 mg/L for Afuze, Odagbo and Owukpa Coal Mines respectively. Apart from acidity, sulphates (SO_4^{2-}) have been described as the most important geochemical indicator of acid mine drainage (Thisani *et al.,* 2020). AMD is known to have an anomalously high SO_4^{2-} value (Jiao *et al.,* 2023). The concentrations of SO_4^{2-} in Odagbo Mine are very high (Figure 4). In support of this finding, different research revealed that mine water has unusually high SO_4^{2-} values (Ezeigbo & Ezeanyim, 1993; Nganje *et al.,* 2010; Ozoko, 2015; Obiadi *et al.,* 2016). Ezeigbo & Ezeanyim (1993) and Nganje *et al.,* (2010) in their separate works observed that the concentrations of SO_4^{2-} were high in mine water and exceeded WHO's specified limits. In the latter research, SO_4^{2-} concentration was 517 mg/L. From a study conducted in Onyeama Coal Mine to unravel the geochemistry of heavy metals, Ozoko (2015) reported the occurrence of SO_4^{2-} in excess of >300 mg/L. High SO_4^{2-} and Fe contents, and acidity with low pH value together define the chemistry of AMD (Jiao *et al.,* 2023; Soda & Nguyen 2023). This observation is in agreement with the findings of this study. Odagbo Mine recorded the highest SO_4^{2-} concentration and acidity a very low pH value. Therefore, Odagbo Mine can be regarded as acidic with extremely high Fe concentration (Soda & Nguyen 2023), Class I- AMD (Hill, 1968) and Class 0- highly concentrated and acidic AMD (Thisani *et al.,* 2020) (Table 3).

The concentration of iron (Fe) in the study locations exceeded the permissible limit (Figure 5). The concentrations ranged between 1.12 mg/L and 10.25 mg/L in Afuze Coal Mine, 6.70 mg/L and 113.1 mg/L in Odagbo Coal Mine and 10.10 mg/L and 40.12 mg/L in Owukpa Coal Mine. The high content of iron (Fe) is a characteristic nature of mine water while its threshold has remained an important geochemical indicator used in the classification of acid mine drainage (Thisani *et al.,* 2020; Jiao *et al.,* 2023; Soda & Nguyen, 2023). Fe concentrations in all the water samples are high. Using the classification framework of Soda & Nguyen (2023), the mine waters of Afuze Coal Mine and Owukpa Coal Mine are grouped into Class 6 (acidic with high Fe concentration) while the mine water of Odagbo is grouped into Class 7 (of acidic with extremely high Fe concentration). The high concentration of Fe in mine water is consistent with all research on the geochemical characterization of mine waters (Ezeigbo & Ezeanyim, 1993; Hatar *et al.,* 2013; Salufu & Salufu, 2014; Sikakwe *et al.,* 2015; Obiadi *et al.,* 2016; Momoh *et al.,* 2017; Akpan *et al.,* 2021). Whereas Ezeigbo & Ezeanyim (1993), Hatar *et al.,* (2013), Salufu & Salufu (2014) and Akpan *et al.,* (2021) reported high values of Fe in their separate researches, Nganje *et al.,* (2010), Sikakwe *et al.,* (2015), Obiadi *et al.,* (2016) and Momoh *et al.,* (2017) gave numerical values of Fe to be 5.14 mg/L to 6.34 mg/L, 5.14 mg/L, 0.467 mg/L to 12.62 mg/L and 5.80 mg/L respectively.

High Al content in mine waters have been reported in different studies of mine water by different authors (Nganje *et al.,* 2010; Sikakwe *et al.,* 2015; Akpan *et al.,* 2021). According to Nganje *et al.,* (2010), the mean values of Al for both dry and wet seasons for Okpara Coal Mine were 1.14 mg/L and 4.30 mg/L respectively. In another study in which acid mine drainage of Okpara Coal Mine was evaluated, Sikakwe *et al.,* (2015) reported an Al concentration of 4.30 mg/L. In a separate study on the chemical characterization of discharges from two derelict coal mine sites in Enugu, Akpan *et al.,* (2021) showed high Al concentrations higher than WHO permissible limit.

Conclusions and Recommendations

All the geochemical indicators including pH, acidity, sulphates, iron, and aluminium concentrations varied significantly with sample type (mine water, stream, mine pit, and tunnel). The values are higher in pits and tunnels than in the streams. The mines ranged from weakly acidic to strongly acidic water with acidity values that ranged from 0.05 to 1,730 and low pH values that ranged from 3.24 to 6.48. Using the distribution and variability of geochemical indices, the study aimed at classifying the coal mines. Afuze Mine is classified into Class I (Acid Mine Drainage), Odagbo Mine belongs to Class 0 of highly concentrated and acidic AMD with extreme Fe content whereas Owukpa Mine belongs to Class II of partially oxidized and/or neutralized.

Afuze and Odagbo Coal Mines have high acidity and high concentrations of Fe and Al. Bioremediation of the mine water using acidophilic microorganisms can be applied to neutralize the high acidity of water. Hyperaccumulators of heavy metals such as sunflower (*Helianthus annuus* L.) and hybrid poplar (*Populus deltoides*) can be used to remove heavy metals from the soil and water

References

Akcil, A., & Koldas, S. (2006). Acid Mine Drainage (AMD): causes, treatment and case studies. *Journal of Cleaner Production*, *14*(12-13), 1139-1145

Akpan, L., Tse, A. C., Giadom, F. D., & Adamu, C. I. (2021). Chemical characteristics of discharges from two derelict coal mine sites in Enugu Nigeria: implication for pollution and acid mine drainage. *Journal of Mining and Environment*, *12*(1), 89-111.

Alpers, C. N., & Nordstrom, D. K. (1999). Geochemical modelling of water-rock interactions in mining environments. *Reviews in economic geology*, *6*, 289-324.

American Public Health Association, APHA (2004). Standard Methods for the Examination of Water and Wastewater, 21st ed. Washington, DC.

Ezeigbo, H., & Ezeanyim, B. (1993). Environmental pollution from coal mining activities in the Enugu area Anambka State Nigeria. *Mine Water and the Environment*, *12*, 53-61.

Gray, N. (1998). Acid mine drainage composition and the implications for its impact on lotic systems. *Water Research*, *32*(7), 2122-2134.

Hatar, H., Rahim, S. A., Razi, W. M., & Sahrani, F. K. (2013). Heavy metals content in acid mine drainage at abandoned and active mining areas. AIP conference proceedings,

Hill, R.D. (1968). Mine Drainage Treatment: State of the Art and Research Needs; U.S. Department of the Interior, Ed.; Mine Drainage Control Activities, Federal Water Pollution Control Administration: Cincinnati, OH, USA, 1968.

Jiao, Y., Zhang, C., Su, P., Tang, Y., Huang, Z., & Ma, T. (2023). A review of acid mine drainage: Formation mechanism, treatment technology, typical engineering cases and resource utilization. *Process Safety and Environmental Protection*.

Lazareva, E., Myagkaya, I., Kirichenko, I., Gustaytis, M., & Zhmodik, S. (2019). Interaction of natural organic matter with acid mine drainage: In-situ accumulation of elements. *Science of The Total Environment*, *660*, 468-483.

Momoh, A., Rotji, E. P., Odewumi, S. C., Opuwari, M., Ojo, O. J., & Olorunyomi, A. (2017). Preliminary investigation of trace elements in acid mine drainage from Odagbo coal mine, North central, Nigeria. *Journal of Environmental and Earth Science*, *7*(1), 1-7.

Nganje, T. N., Adamu, C. I., Ugbaja, A. N., Ebieme, E., & Sikakwe, G. U. (2011). Environmental contamination of trace elements in the vicinity of Okpara coal mine, Enugu, Southeastern Nigeria. *Arabian Journal of Geosciences*, *4*(1), 199-205.

Nwajide, A. (1989). Paleographic setting for coal sequences in the Benue Trough Complex, Upper Cretaceous, pp. 1-8.

Obi, D. Ekwueme, B.N. & Akpeke, G.B. (2008). Reserve Estimation of Barite Deposits using Geological and Geophysical Investigations in Cross-River State, South-eastern Nigeria. *Journal of Environment and Earth Science,* 4(8); 18-38.

Obiadi, I., Obiadi, C., Akudinobi, B., Maduewesi, U., & Ezim, E. (2016). Effects of coal mining on the water resources in the communities hosting the Iva Valley and Okpara Coal Mines in Enugu State, Southeast Nigeria. *Sustainable Water Resources Management*, *2*, 207-216.

Offodile M, E (2002) Groundwater study and development in Nigeria. Jos Macon Geology and Engineering Services, Nigeria .

Ofoegbu, C. O., Umeji, O. P., Uzoegbu, M. U., & Onyemesili, C. A. (2013). Geology and mineral resources of the Anambra Basin, Southeastern Nigeria. Journal of Geology and Mining Research, 5(3), 50-60.

Okeke, H. C., Ngah, S. A., Okeke, O. C., & Ngene, C. E. (2018). Hydrogeological assessment of the Mamu Formation in Onyeama Mine Area, Enugu, Nigeria. Journal of Geography, Environment and Earth Science International, 17(2), 1-9.

Onoduku, U., Mohammed, M., Ako, T., Onawola, J., & Musa, R. (2019). Elemental Characteristics of some Nigerian Coal Deposits: Implication for the origin of the coals.

Ozoko, D. (2015). Heavy Metal Geochemistry of Acid Mine Drainage in Onyeama Coal Mine, Enugu, South-eastern Nigeria. *Journal of Environment and Earth Science*, 2015; 3-17.

Salufu Samuel, O., & Salufu Emmanuel, O. Integrated Study of Acid Mine Drainage and its Environmental Effects on Onyeama Mine and Environs, Enugu, Nigeria.

Sikakwe, G., Ephraim, B., Nganje, T., Ntekim, E., & Amah, E. (2015). Geoenvironmental impact of Okpara coal mine, Enugu, Southeastern Nigeria. *Adv. Appl. Sci. Res*, *6*(4), 5-16.

Skousen, J., Sexstone, A., Cliff, J., Sterner, P., Calabrese, J., & Ziemkiewicz, P. (1999). Acid Mine Drainage Treatment with a Combined Wetland/Anoxic Limestone Drain: Greenhouse and Field Systems'. *Pat*, *13*, 19.

Soda, S. & Nguyen, T.T. (2023). Classification of Mine Drainages in Japan Based on Water Quality: Consideration for Constructed Wetland Treatments. *Water, 15*(7); 1258- 1272.

Thisani, S. K., Kallon, D. V. V., & Byrne, P. (2020). Geochemical classification of global mine water drainage. *Sustainability*, *12*(24), 10244.

Utom, A. U., Odoh, B. I., & Egboka, B. C. (2013). Assessment of hydrogeochemical characteristics of groundwater quality in the vicinity of Okpara coal and Obwetti fireclay mines, near Enugu town, Nigeria. *Applied Water Science*, *3*, 271-283.

Valente, T., & Gomes, C. L. (2007). The role of two acidophilic algae as ecological indicators of acid mine drainage sites. *Journal of Iberian Geology*, *33*(2), 283-294.

Wang, X., Jiang, H., Zheng, G., Liang, J., & Zhou, L. (2021). Recovering iron and sulfate in the form of mineral from acid mine drainage by a bacteria-driven cyclic biomineralization system. *Chemosphere*, *262*, 127567.

Obaje, N.G. (2009). Geology and Mineral Resources of Nigeria. Springer Dordrecht, Heidelberg. London, p. 211.

Reservoir assessment of a field in Niger Delta: Implication for CO_2 storage

Chioma Oluchukwu Maduewesi[1&3*]., Adewale Dosunmu[1&2] and Uche Osokogwu [1&2]

[1]Emerald Energy Institute, University of Port Harcourt, Choba, Rivers State; and Department of Geology, University of Nigeria, Nsukka, Nigeria

[2] Department of Petroleum Engineering, University of Port Harcourt, Choba, Rivers State; and Emerald Energy Institute, University of Port Harcourt, Choba, Rivers State Nigeria

[3] Department of Geology, University of Nigeria, Nsukka, Nigeria

Corresponding author: chioma.maduewesi@unn.edu.ng

Abstract

Carbon dioxide (CO_2) capture and storage (CCS) is presented as an alternative measure and promising approach to mitigate the large-scale anthropogenic CO_2 emission into the atmosphere. In this context, CO_2 sequestration into depleted oil and gas reservoirs is a practical approach as it boosts the recovery and facilitates the permanent storing of CO_2 into the candidate sites. However, the estimation of CO_2 storage capacity and properties in subsurfaces is a challenge to kick-start CCS worldwide. Thus, this paper characterizes the reservoirs of a field to tackle the challenge of CO_2 storage in Niger Delta. To achieve this work's ultimate goal, the schulmberger Petrel software was used for evaluation of the structural and petrophysical parameters of six wells, which includes: faults for trapping mechanism, porosity and permeability. Eleven reservoir (A-K) storage units were delineated and reservoir A selected for CO_2 storage. The results demonstrated significant trapping structures, with good closure dependent fault pattern for CO_2 storage without leakage. Also, the reservoir of study indicates 0.01 – 0.35 porosity and 0.5 -350MD permeability ranges respectively, which is a good indication of the ability of the reservoir rocks to retain and allow fluid to flow. Thus, reservoir A was chosen to possess the potential of CO_2 storage and utilization due to its structural ability in Onshore Niger Delta.

Keywords: Reservoir characterization; Carbon dioxide Storage; Reservoir Parameters.

1 INTRODUCTION

The greenhouse gas (GHG) mitigation is becoming a stronger legislative priority in Nigeria as renewable generation technologies (e.g.wind and power) are still unable to provide dispatchable electric power in the country, therefore fossil fuels are likely to remain the principal source of energy. Emissions from oil extraction and energy use will continue to drive atmospheric concentrations of CO2 upwards unless energy conversion systems can be designed to otherwise dispose CO2 generated from combustion and flaring. The Nigeria's Niger Delta ranks the second highest gas-flaring nation behind Russia (Hansen, 2004) and efforts to mitigate this effect has brought about one of the United Nations' Sustainable Development Goals (SDGs) of reducing global concentrations of CO_2 in the atmosphere (Griggs *et al.,* 2013). Studies have shown that Carbon Capture Utilization Sequestration (CCUS) is one of the methods set for greenhouse gas emission reduction before 2030 as demanded by the Kyoto Protocol. This transcends towards cleaner energy which will help to achieve the goal of the United Nations (UN) Framework Convention on Climate Change. Reservoir characterization and accurate mapping of the reservoir's structural and stratigraphic features, along with understanding the rock properties, is crucial for designing optimal injection and storage strategies. However, CCS is yet to be implemented on a local or regional scale in Nigeria. Previous studies on CCS in Nigeria have, so far, mainly focused on the fundamental science of CCS, the present status of global CCS development, terrestrial sequestration and the benefits/potential risks of its future implementation (Galadima and Garba 2008; Akpanika Et al., 2015; Yelebe and Samuel 2015; Ibrahim Et al., 2019). The stratigraphic and structural competence of some reservoir units within the Niger Delta for carbon storage has also been carried out by a few authors (Ojo and Tse 2016; Umar et al. 2019a,). The study area in this research is typically characterized by several growth faults associated with rollover anticlinal structures typical of the Niger Delta extensional zone (Doust and Omatsola 1990). We also recognize that while some authors have worked on the applications of 3D fault seal attributes to characterize fault planes, hydrocarbon predictions and prospectivity in the Niger Delta basin (Ifeonu, 2015; Ejeke et al. 2017; Adagunodo et al. 2017; Anyiam et al. 2017), few have commented on the implications of these on CO_2 storage as well as highlighted the importance of seismic data conditioning by applications of structure-orientated filtering seismic attributes which takes account of bed estimated orientations and thereby reduces the noise content without losing information related to edges of geologic units (Azevedo 2009; Qi 2018) before determining the framework of faults within the field. Thus, the aim of this research is to characterize the field and select a prolific reservoir for possible CO_2 storage.

1.1 Geology of the study area

Within the Gulf of Guinea, the Niger Delta Basin (figure 1) covers an area of about 140,000 km2 and is located at the southernmost extremity of the elongated intracontinental Benue Trough (Klett et al., 1997; Pochat et al., 2004). To the west, it is separated from the Dahomey (or Benin) Basin by the Okitipupa basement high, and to the east, it is bounded by the Cameroun volcanic line. Its northern margin transects several older (Cretaceous) tectonic elements—the Anambra Basin, Abakaliki Basin, Afikpo Syncline, and the Calabar Flank (fig. 2). The delta, based on Ekweozor and Daukoru (1994) and Tuttle et al., (1999) began its development in the Eocene with the accumulation of sediments that are now about 10 kilometers thick. The area is geologically a sedimentary basin, and consists of three basic Formations: Akata, Agbada and the Benin Formations. The Akata is made up of thick shale sequences and it serves as the potential source rock. It is assumed to have been formed as a result of the transportation of terrestrial organic matter and clays to deep waters at the beginning of Paleocene (Tuttle et al., 1999). According to Doust and Omatsola (1990), the thickness of this formation is estimated to about 7,000 maters thick, and it lies under the entire delta with high overpressure. Agbada Formation is the major oil and gas reservoir of the delta. It is the transition zone and consists of intercalation of sand and shale (paralic siliciclastics) with over 3700 meter thick and represents the deltaic portion of the Niger Delta sequence (Doust and Omatshola, 1990; Tuttle et al., 1999). Agbada Formation is overlain by the top Formation, which is Benin. Benin Formation is made of sands of about 2000m thick (Avbovbo, 1978).

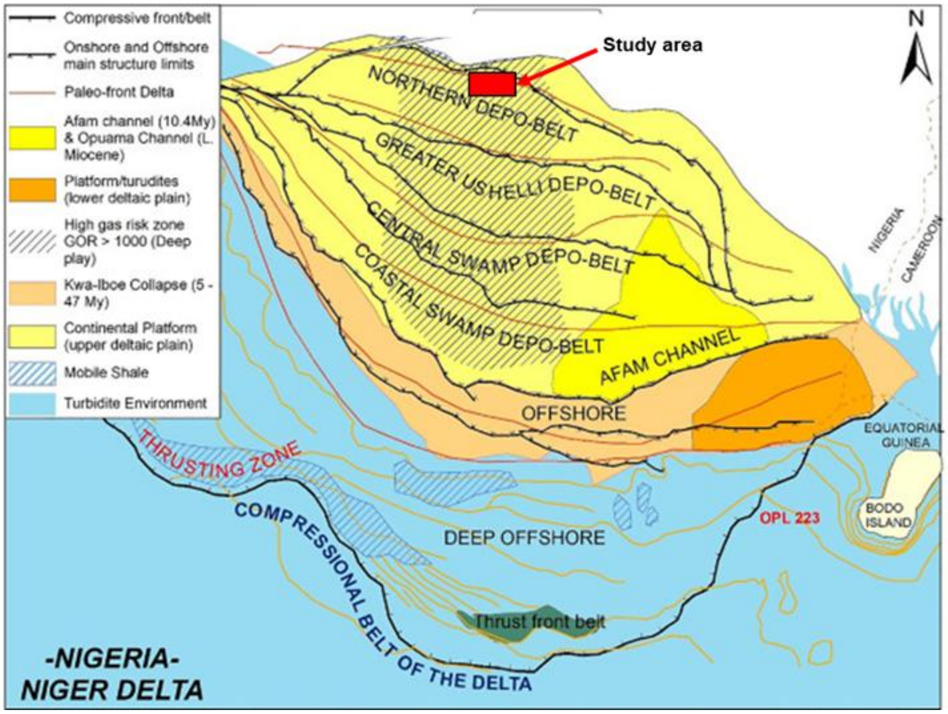

Figure 1: Geologic map of the Niger Delta Basin showing depo-belts and structural elements (Obiadi and Obiadi, 2016)

The field under study is a gas condensate field that is situated in the onshore Niger Delta, in the Northern depo-belt (figure 1). The field, which spans approximately 7 kilometers in the strike direction and 3 kilometers in the dip direction, has been explored and developed through the drilling of wells.

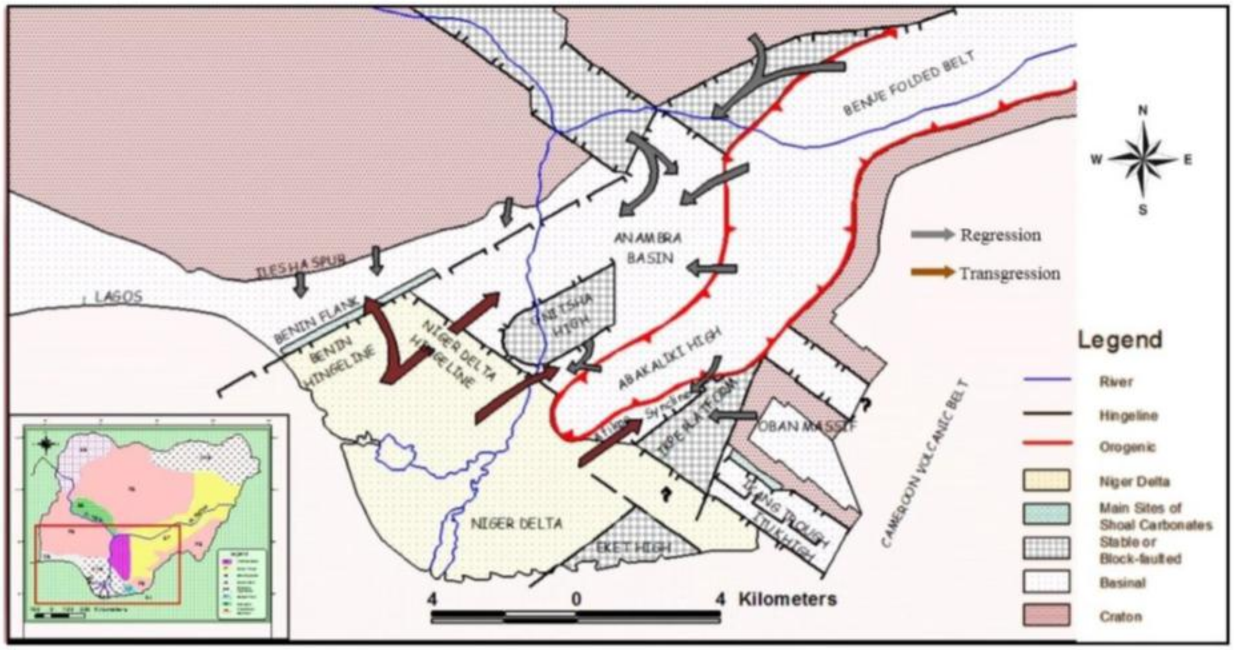

Figure 2: Tectonic setting and structural elements of the Niger Delta Basin (After Kogbe, 1989).

In the vicinity of the Field, a three-part stratigraphic sequence can be observed, which is characteristic of the stratigraphy encountered in the Niger Delta region (as illustrated in figure 3). The oldest sequence identified in the area is the Akata deep marine shales, which exhibit very low sand development. Overlying the Akata sequence is the paralic Agbada sequence, characterized by alternating layers of sand and shale, followed by the massive, sandy, fluvial-dominated Benin Formation.

Interestingly, all of the field's hydrocarbon-bearing reservoirs were found within the Agbada sequence, located in the northern depo-belt of the Niger Delta (as indicated in figure 1). The reservoirs are typically composed of sand-shale pairs, with the overlying shale acting as a seal to the underlying hydrocarbon-bearing sand reservoir. It is worth noting that the sedimentary environment of the area played a crucial role in the accumulation and preservation of hydrocarbons in the reservoirs in the field.

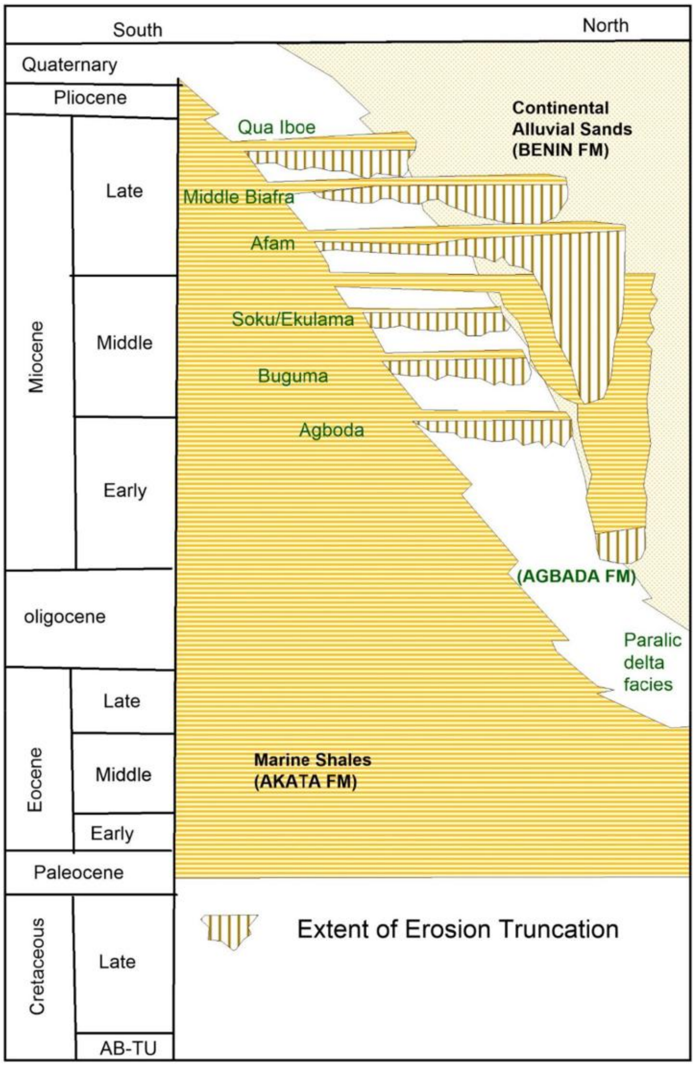

Figure 3: Stratigraphic column showing the three formations of the Niger Delta modified after Doust and Omatsola 1990.

2 Materials and Methods

The study integrated the use of available data (not limited to well logs; Gamma Ray GR, Resistivity and Neutron log), 3D seismic section and some software for research analysis. The software that will be used includes: The Schlumberger's "PETREL" and Senergy's "Interactive Petrophysics (IP)" were the software used in the analyses of the data. Petrel was used in mapping horizons and faults on the seismic data, correlating wells across the field, and 3D modeling while IP was used for the petrophysical evaluation.

2.1 Reservoir identification and petrophysical analysis

Reservoirs were identified by using a combination of the log signatures of gamma ray, resistivity and neutron-density logs. Intervals that have high resistivity are considered to be hydrocarbon-bearing while low resistivity zones are water-bearing intervals. A combination of the gamma ray and resistivity logs were used to differentiate between the hydrocarbon and non-hydrocarbon bearing units. The scale increases from left to right, with a range of 0-150 API for the gamma ray log and 0.2-2000 ohm-metre for the resistivity (figure 4). As the hydrocarbon saturation increases, resistivity also increases; on the other hand as water saturation increases, the resistivity decreases. The gamma-ray logs were then integrated with the resistivity and neutron density logs to identify the distribution of different reservoir fluids (i.e. water and hydrocarbon) across the wells. Petrophysical properties are very important parameters when evaluating reservoirs for identification and general quality of CO_2 storage units within a field. Petrophysical values derived from the Interactive Petrophysics software (IP 2021) were upscaled and modeled with the aid of the petrophysical modeling procedure in the Schlumberger Petrel software. The sequential Gaussian simulation algorithm was the statistical method employed for the distribution of the petrophysical parameters (effective porosity (ϕ), permeability (mD), and water saturation (Sw)), cross sections in the NW and SE directions were also extracted to recognize both vertical and lateral property distributions in the reservoir.

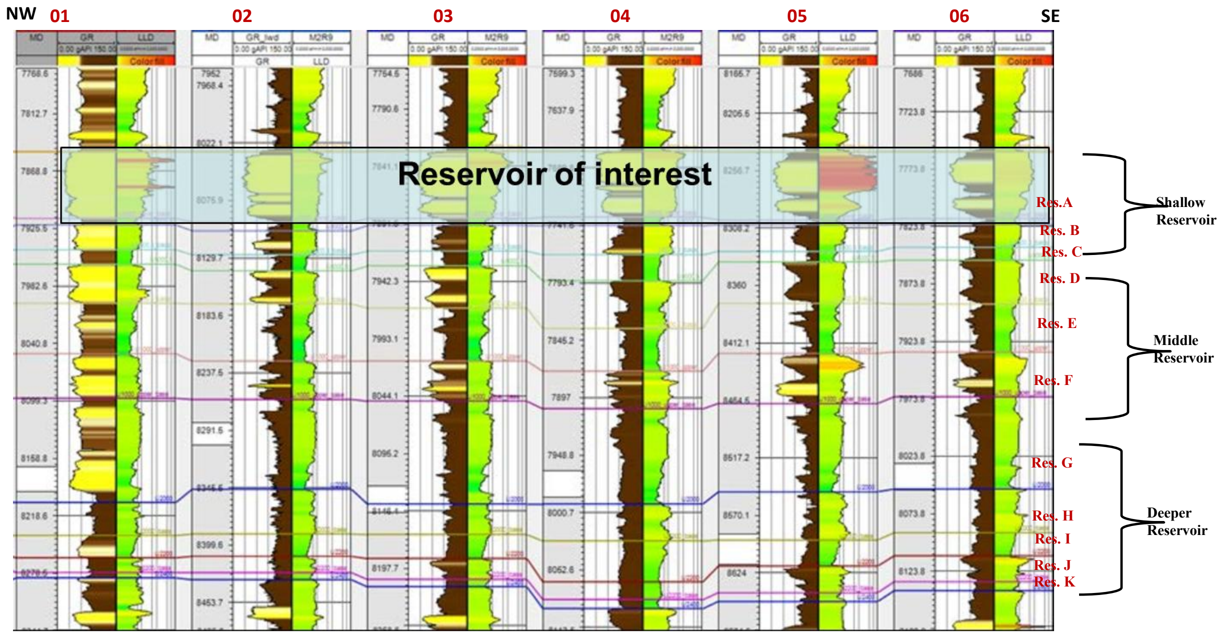

Figure 4: Well correlation panel across the field

2.2 Seismic interpretation

The seismic volume is imported into a user defined folder in SEG-Y format and then realized. From the realized volume, Inline and Xline are inserted. A 3-D window and a new interpretation window were used to view and also to carry out fault mapping (figure 5). The faults were mapped on the Xlines and the continuity viewed on the Inlines.

2.3 Picking of Faults

The conditions for fault mapping used were as follows:

(a) Abrupt termination of reflection events

(b) Displacement or distortion of reflection

To generate fault models for faulted levels, the fault centerlines were digitized from provided fault polygons. For the model boundaries, boundary polygons were generated from the depth grids provided and then modeled as pillars. The fault models were then snapped to the bounding depth grids, ensuring that the pillar grid skeletons followed the structural trend of the reservoir.

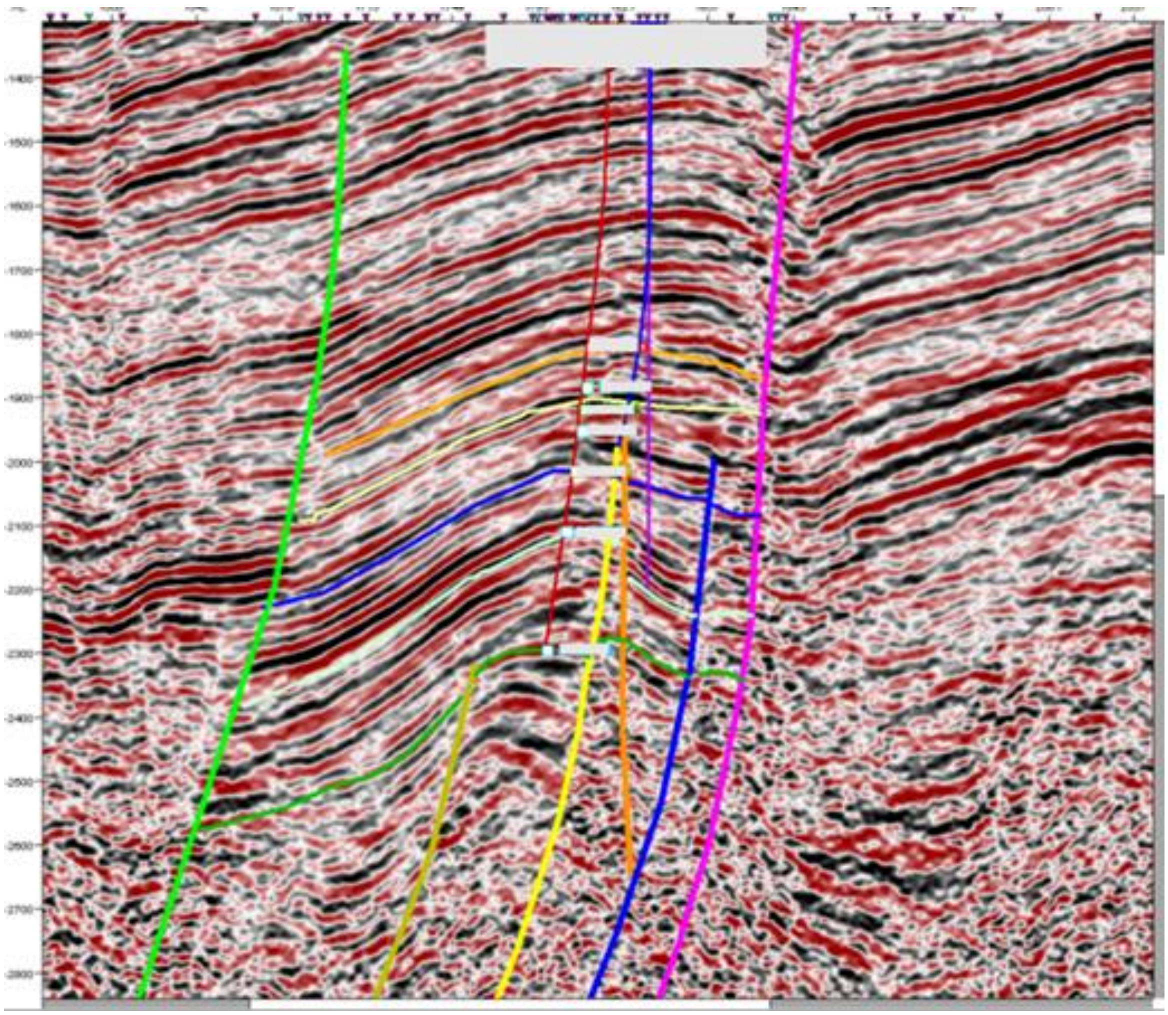

Figure 5: 3D seismic section of the study area

2.4 Structural analysis

The faults that intercepted the reservoir of interest were modeled and quality-checked using interpreted faults and the respective top structural maps. The fault models (figure 6) constructed were integrated with the top and base depth structural maps of the reservoir to build a 3D structural grid. Facies (sand and shale) identified from gamma-ray logs from wells as well as key rock properties sensitive to fault sealing potential including, porosity and permeability estimated from petrophysical analysis were then upscaled into the mesh-like cellular framework of the three-dimensional structural model. To extrapolate estimates at unknown locations away from well locations, standard geostatistical techniques rely on known data points from multiple locations (e.g. drilled wells) to reduce uncertainties associated with the estimated unknown data values.

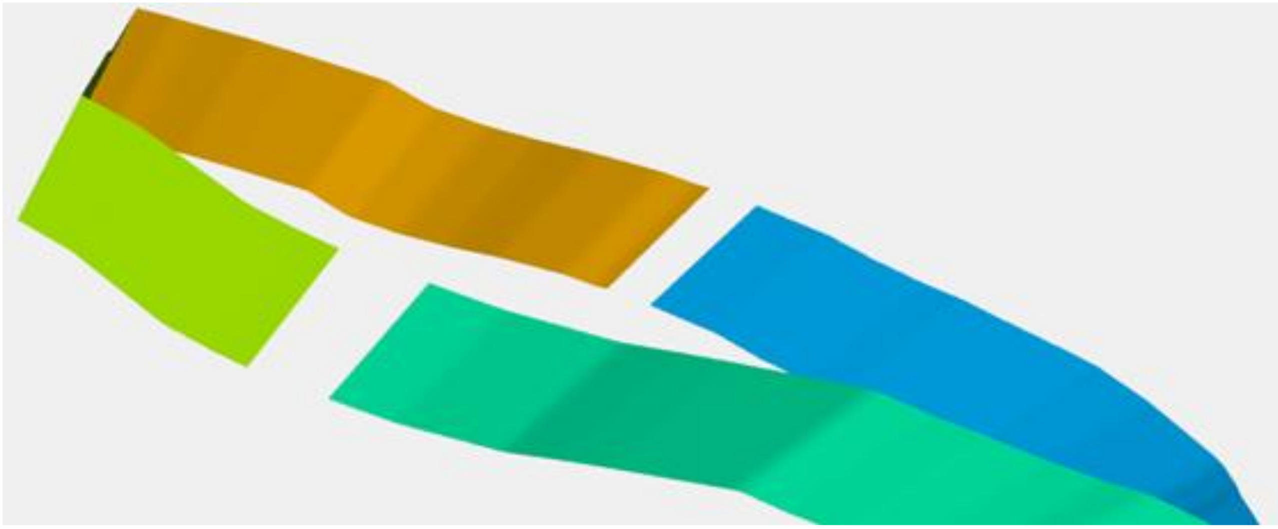

Figure 6: Fault model

3 Results and discussion

3.1 Reservoir identification and petrophysical analysis

Eleven reservoir units were delineated across the wells. The reservoirs comprising shallow reservoir, middle reservoirs and deep/lowermost reservoirs are identified from wireline logs interpretation (figure 4). Reservoir A was selected as the reservoir of interest because it possesses good sand packages and volume of hydrocarbon across the entire wells The deep resistivity logs indicate all the storage units are gas and water-bearing. Estimated porosities range from 0.01 to 0.35 and permeabilities range from 0.5 to 350 mD (Table 1). However, the estimated water saturation has an average value of 0.4 across the reservoir of interest giving indication of hydrocarbon accumulations. The petrophysical estimates suggest that the reservoirs have varying properties of high to low porosity and varying permeabilities. However, the shallow reservoirs have better reservoir properties than the middle and lowermost reservoir due to good sand packages which is continuous across the wells.

Table 1: Summary of petrophysical analysis of reservoir A

WELLS	TOP (ft)	BASE (ft)	THICKNESS (ft)	POROSITY	K (md)	S_W v/v
01	7840.8	7919.3	78.5	0.15	150	0.02
02	8027.5	8097.3	69.8	0.25	89	0.05
03	7826.0	7891.5	65.5	0.21	125	0.01
04	7679.3	7741.6	62.3	0.22	130	0.03
05	**8226.6**	**8301.2**	**74.6**	**0.25**	**200**	**0.04**
06	7758.8	7823.8	65.0	0.30	270	0.05

3.2 Seismic interpretation and fault picking

Different faults were identified and mapped across the seismic data. Most of the faults seen on the seismic section (figure 5) were not continuous across the seismic volume, but major and minor faults that were continuous were mapped. The prominent faulting styles include growth faults with associated rollover anticlinal structures. The faults have a north-west south-east orientation as well as a north-east–south-west direction. Observations from a seismic section indicate that most of the faults have affected all the storage units (figure 5). The depth structural map of reservoir of interest (shallow reservoir) is shown as a representative depth map (figure 7).

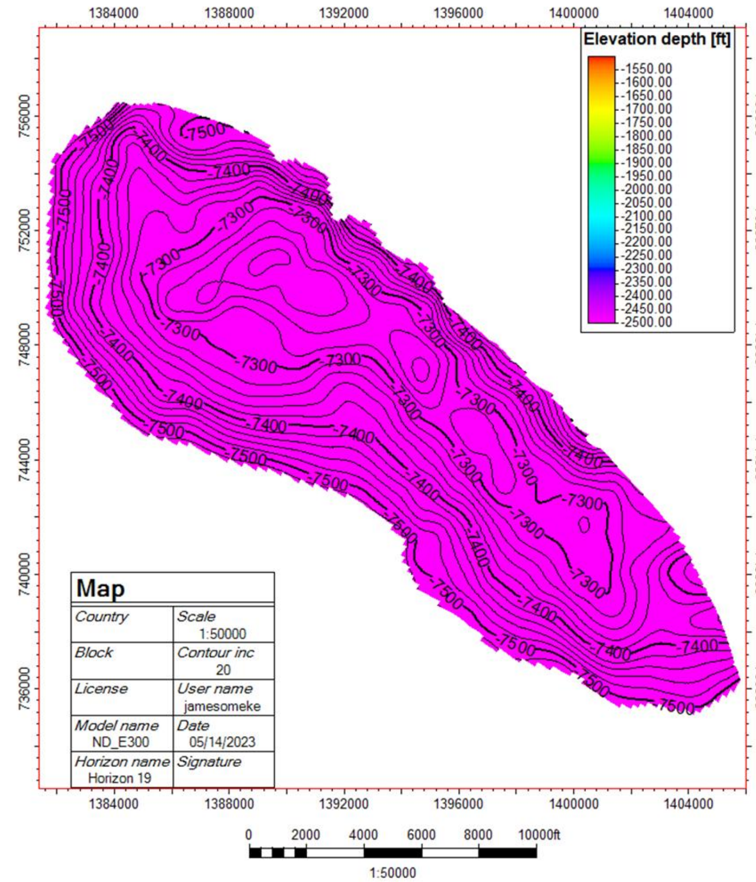

Figure 7: Depth structural map

3.3 Structural interpretation

The field structure is a prime example of a northern depo-belt structure, characterized by the presence of a rollover anticline situated in the hanging wall of a significant listric fault, with a WNW-ESE strike direction. At certain levels, the structure exhibits a 4-way dip closure, while at others, it is dependent on an up-dip fault seal for containment. The reservoir under study is a 4-way closure (as depicted in figure 6). The field is located in an area affected by several synthetic and antithetic faults, some of which may not be detectable by seismic imaging. However, a contemporary 3D seismic dataset of high quality fully encompasses the field, allowing for a relatively confident time interpretation (figure 5). The 3D fault models of the mapped faults reveal their three-dimensional distribution and orientation across the field (Fig. 6). The faults towards the north central part of the field are four-way dependent closure as revealed by the 3D fault model of the field. The facies from the gamma ray log motifs show the distribution of sands and shale across all the mapped reservoirs. The reservoir showed good quantity of sands across the reservoirs. The permeability values suggest high permeability within sands and low permeability within shales.

4 Conclusion

Carbon capture, utilization and storage remain an important and essential technology for countries and industries to reduce worldwide environmental change, with underground storage of carbon dioxide in geological formations as a core of carbon sequestration, especially in non-renewable energy-centered nations.

Reservoir A was selected as the reservoir of interest for CO_2 storage. The reservoir was identified to possess a very good property quality suitable for anthropogenic CO_2 storage, with average porosity and permeability range of 0.35 and 350mD respectively.

The field of study has demonstrated a fault model which exhibits a four-way dip closure structure and a North-West South East trend, with the ability to retain gas without significant leakage, indicating their potential for containing CO2 as well.

It is recommended that numerical simulation incorporated with the present Petroleum Industry Act (PIA) under the gas fiscal regime be studied to evaluate the potential of gas utilization for revenue while storing anthropogeneic carbon dioxide.

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DECLARATIONS

Conflict of Interest The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

5 REFERENCE

Adagunodo, T. A., Sunmonu, L. A. and Adabanija, M.A., 2017. Reservoir characterization and seal integrity of Jemir field in Niger Delta, Nigeria. Journal of African Earth Sciences, vol. 129, pp. 779–791.

Akpanika OI, Etim JO, Udoh FD (2015) Diverting CO2 emissions from the atmosphere through capture and geological sequestration: the journey so far. Journal of Environmental Earth Science 5(2):42–52

Anyiam, O. A., Maduewesi, C. O., Ibemesi, P. O., and Okwara, I. C. (2017). Reservoir Quality Studies and Prospect Identification of a field in the Coastal Swamp Depobelt, Niger Delta. *Petroleum and Coal*, *59*(4).

Avbovbo A.A. (1978). Geothermal gradients in the Southern Nigerian basin. Bulletin Candian Petroleum Geology 26(2):268–274

Azevedo L. (2009). Seismic attributes in hydrocarbon reservoirs characterization. Aveiro University, Aveiro, pp109–112

Bachu, S. (2000). Sequestration of CO2 in geological media: Criteria and approach for site selection in response to climate change. Energy Conversion and Management 41, 953–970.

Bachu, S. (2002). "Sequestration of CO2 in geological media in response to climate change: road map for site selection using the transform of the geological space into the CO2 phase space." Energy Conversion and Management 43 (1): 87-102.

Bachu, S. (2003). "Screening and ranking of sedimentary basins for sequestration of CO2 in geological media in response to climate change." Environmental Geology 44 (3): 277-460 289.

Doust H., Omatsola E. (1990). Divergent/passive margin basins. American. Association of Petroleum Geology Memoir 48:201–238

Ejeke C.F., Anakwuba E.E., Preye I.T., Kakayor O.G. and Uyouko I.E. (2017). Evaluation of reservoir compartmentalization and property trends using static modelling and sequence stratigraphy. Journal of Petroleum Exploration and Production Technology 7:361–377.

Ekweozor, C. M. and Daukoru, E. M., 1994. Northern delta depobelt portion of the Akata–Agbada(!) petroleum system, Niger Delta, Nigeria. In: L. B. Magoon and W. G. Dow, eds, The petroleum 157 system—from source to trap: American Association of Petroleum Geologists Memoir 60, pp. 599–613.

Galadima A, and Garba Z.N. (2008). Carbon capture and storage (CCS) in Nigeria. Fundamental Science Potential Implementation Risks Sci World J 3(2):95–99. https:// doi. org/ 10. 4314/ Swj. V3i2. 51802

Griggs, D., Stafford-Smith, M., and Gaffney, O. (2013). Policy: Sustainable development goals for people and planet. *Nature* **495** (7441): 305-307.

Hansen J. (2004). Defusing the global warming time bomb. Science American 290(3):68–77

Ibrahim M.A., Abubakar B.Y, and Balarabe M.L. (2019). Sequestrated carbon content in tree species and diurnal temperature influence for adaptive climate change resilience in Nigeria. In: Leal FW (ed) Handbook of climate change resilience. Springer, Cham, pp 3-27

Ifeonu I. (2015). Fault seal attributes as parameters for hydrocarbon column prediction in central swamp of the Niger delta. https://doi. org/ 10. 13140/ RG.2. 1. 4654. 4725.

Klett, T. R., Ahlbrandt, T. S., Schmoker, J. W. and Dolton, J. L., 1997. Ranking of the world's oil and gas provinces by known petroleum volumes: U.S. Geological Survey Open-file Report-97-463, CD-ROM.

Kogbe, C. A., 1989. The Cretaceous Paleocene Sediments of Southern Nigeria. In C. A. Kogbe (Ed.), Geology of Nigeria, Jos: Rock View Ltd, pp. 320–325

Obiadi, I. I, and Obiadi, C. M. (2016). Structural deformation and depositional processes: Insights from the greater ughelli depobelt, Niger Delta, Nigeria. Oil Gas Res. 2 (3), 65-82

Ojo, A. C., and Tse, A. C. (2016). Geological characterisation of depleted oil and gas reservoirs for carbon sequestration potentials in a field in the Niger Delta, Nigeria. Journal of Applied Sciences and Environmental Management, 20(1), 45.

Pochat, S., Castelltort, S., Van Den Driessche, J., Besnard, K. and Gumiaux, C., 2004. A simple method of determining sand/shale ratios from seismic analysis of growth faults: An example from upper Oligocene to lower Miocene Niger Delta deposits. American Association of Petroleum Geologists, vol. 88 (10), pp. 1357–1367.

Qi J., Lyu B., AlAli A., Machado G., Hu Y. and Marfurt K. (2018). Image processing of seismic attributes for automatic fault extraction. Geophysics. https:// doi. org/ 10. 1190/ geo20 18- 0369.1

Tuttle, W. L. M., Brownfield, E. M. and Charpentier, R. R., 1999. The Niger Delta Petroleum System. Chapter A: Tertiary Niger Delta (Akata-Agbada) Petroleum System, Niger Delta Province, Nigeria, Cameroon and Equatorial Guinea, Africa. U.S. Geolgical Survey, Open File Report. 99-50-H.

Umar B.A., Gholami R., Shah A.A, and Nayak P. (2019a). Preliminary structural and stratigraphic assessment of an onshore field for CO2 re-injection in the Niger Delta Basin Nigeria. Journal of Natural Gas Science Engineering 69:102919

Umar B.A., Raoof G., Prasanta N., William S.D, and Afroz A.S. (2019b.) Normal fault geometrical trends and interactions in an onshore oilfield Niger Delta Basin, Nigeria. Journal of Petroleum Science and Engineering 177:579–593

Yelebe Z.R. and Samuel R.J. (2015). Benefits and challenges of implementing carbon capture and sequestration technology in Nigeria. International Journal of Engineering Science 4:42–49

ANALYSIS OF THE EFFECT OF TRAFFIC CONGESTION ON ROAD TRANSPORTATION OF AGRICULTURAL PRODUCTS IN SOUTHWEST NIGERIA

Ajao Oluseyi Stephen, Akpoghomeh Osi, S

Nigerian Institute of Transport Technology (NITT), Zaria

ajasent477@gmail.com, akpoghomeh@yahoo.com

Abstract

This study investigated the effects of road congestion on the transportation of agricultural commodities via roadways in selected southwestern states of Nigeria. The data collection methodology employed in this study was the utilization of a cross-sectional survey design, with a sample size consisting of 400 participants. In order to gather data for the research, questionnaires were sent to market dealers and market vendors located in prominent markets across the three states encompassing the study area, namely Ondo, Osun, and Ekiti. The data was effectively displayed through the utilization of tables and charts. Additionally, the association between congested roads and the distribution of agricultural commodities were evaluated by means of regression analysis. The findings of the study indicate that the presence of police officers and armed forces personnel obstructing roads significantly contributes to traffic congestion within the area under investigation. Subsequent investigations have revealed a robust correlation between traffic congestion and the transportation of agricultural products within the designated study region. The study concludes that congested traffic along transportation routes is adversely affecting the inefficient delivery of agricultural goods in the studied area. The report proposes, among several recommendations, the removal of any unauthorized obstacles from the transportation routes within the study region.

Keywords: Road Transportation, Agricultural Product Distribution, Traffic Congestion.

Introduction

The transportation industry plays a crucial role in facilitating economic growth and facilitating the transition of a given region. Transport plays a crucial role in facilitating the movement of individuals and goods, thereby enabling the functioning of the economy and society. It enhances the accessibility of markets and services for businesses and consumers, fosters financial diversity and geographic integration, and ultimately contributes to the overall growth of the broader economy. From a sociological standpoint, transportation facilitates personal mobility, enabling individuals to avail themselves of crucial public services like healthcare and education, as well as gain access to employment opportunities. These factors can significantly impact economic inclusivity and gender parity. Transportation plays a crucial role in facilitating international trade within the contemporary global economy, as no nation can achieve self-sufficiency and instead relies on commodities produced in other regions. Consequently, transportation serves as a vital mechanism for emerging countries to seamlessly incorporate into the globalized economy (Ajiboye and Afolayan, 2009; Tunde and Adeniyi, 2016). Transportation serves as a fundamental element in the geographical organization of a society, hence exerting significant influence on political, economic, and fostering social growth and organization. (Taafee & Gauther, 1998). According to Aderamo (2010), the role of transportation extends beyond its practical function and holds significance in fostering national unity, encouraging social-economic integration, cultivating a sense of fellowship, and facilitating mutual understanding within a diverse society. The significance of transportation is underscored by the presence of the world's largest cities, which are strategically located along various transportation routes, including rail, water, road, and air (Oni, 2010). According to Kandiero (2009), the African Development Bank acknowledges the significance of investing in infrastructure, including transportation, electricity supply, and telecommunications, as a means to foster economic growth, alleviate poverty, and attain the Millennium Development Goals (MDGs). According to Kiprono and Matsumoto (2014), the enhancement of road infrastructure is anticipated to result in an increase in the output price for producers, as well as a decrease in production costs due to the lowered expenses associated with transporting goods and services.

The significance of trucking is undeniably vital, as it represents a crucial stage in the production process that remains incomplete until the goods are ultimately delivered to the end consumers. The presence of road transportation infrastructure plays a pivotal role in the management of economic growth by enhancing accessibility, efficiency, and effectiveness, as highlighted by Ellis and Hine (1998). Moreover, it exerts a significant impact on the fundamental operations of production, distribution, marketing, and consumption across various dimensions. The cost of commodities utilized and the buying power of consumers are also impacted by road transportation (Ellis and Hine, 2003). The determination of time and quality of commodities reaching consumers is contingent upon the characteristics of the roadways along which goods and services are transported. According to Aderamo and Magaji (2010), transportation serves as the primary means by which various segments of society are interconnected. Jegede (1992), as reported by Ajiboye and Afolayan (2009), observed that road transport is the predominant and intricate network. The transportation mode in question encompasses a broad spectrum, offering physical convenience, significant flexibility, and typically serving as the most operationally appropriate and easily accessible method for the conveyance of products and passenger traffic across varying distances, including short, medium, and long hauls. Moreover, it may be argued that a sustainable transportation system is characterized by its ability to effectively fulfill the fundamental access requirements of both individuals and societies, while ensuring safety and promoting the well-being of both human beings and the environment. Additionally, it should strive to achieve fairness and equality in terms of access and benefits, not only within the present generation but also across future generations. The primary objectives of the Road Transportation Policy Framework and Principles are to ensure affordability, efficient operation, provision of a variety of transportation modes, and support for an expanding market (Anita et al., 2003). The primary role of transportation is to mitigate the temporal and spatial disparity that exists between individuals and their engagements.

In a similar vein, the presence of well-developed road infrastructure plays a crucial role in facilitating the effective and timely delivery of agricultural goods across different geographical locations. Consequently, the provision of sufficient road infrastructure enables the accessibility of agricultural products to customers. According to Kareem (2010), the concept of distribution pertains to the process of ensuring that products are accessible within their respective markets, involving the strategic alignment of the appropriate product with the correct location and timing. Distribution encompasses a wide array of operations that pertain to the effective transportation of completed goods from the point of production to the end consumer. According to Musa (2008) and Bamaiyi (2011), several transportation methods are employed for the movement of passengers, agricultural commodities, and manufactured items from areas of supply or production to regions of shortage or consumption throughout different parts of Nigeria. Therefore, the allocation of resources towards the development of road infrastructure, along with other complementary variables that facilitate its efficient functioning, will play a significant role in the monetary, political, and social systems that contribute to the enhancement of a nation's wealth and influence. These efforts also contribute to the expansion of markets and the reduction of obstacles to commerce. According to Kustepeli et al. (2012) and Njoh (2012), as a result of this phenomenon, there is a notable enhancement in productive capabilities and an improvement in the overall accessibility and standard of life for the general population.

Accordingly, Armstrong and Wright (2020) have observed that the transportation of agricultural commodities is a significant challenge in numerous metropolitan areas of Nigeria, with a particular emphasis on the southwest region of the nation. Despite the implementation of various corrective measures by different agencies over time, persistent issues such as traffic congestion, high freight costs, conflicts among herders, and traffic accidents continue to prevail. The current public transportation system fails to meet the demand due to several factors. These include substandard travel experiences, insufficient safety and security measures for passengers, inadequate maintenance and management of highways, and exorbitant and unaffordable travel costs. Furthermore, Musa (2009) revealed that the South Western regions of Nigeria are confronted with various challenges, including crowded road networks, elevated freight costs, disputes among herders, and frequent traffic accidents, which have a significant impact on nearly all state capital cities. As an illustration, Ogun state, previously unacknowledged for its traffic issues, is presently grappling with substantial traffic congestion on multiple urban road networks. The transportation of agricultural products to markets is predominantly reliant on road infrastructure, hence exerting a significant influence on agricultural marketing. This study aims to examine the impact of vehicular travel on the distribution of agricultural products in the southwestern regions of Nigeria. The study aims to investigate the impact of road congestion on the distribution of agricultural products.

Literature Review

Road Transport Infrastructure and Economic Development

The influence of a well-designed road transport infrastructure on economic development can be observed in two distinct manners: as an independent component of production and through its consequential effects on overall productivity progress and subsequent economic advancement (Beyzatlar & Kustepeli, 2011; Kim et al., 2014; Kustepeli et al., 2012). Theoretically, augmenting the funding allocated to road transportation infrastructure is expected to have multiple positive effects on the overall economy. These effects include enhancing economic output and development, influencing the price competitiveness of both domestic and exported goods and services, fostering the establishment of new businesses, impacting employment levels, reducing costs, and enhancing the quality of life (Kim et al., 2014). Calderon and Serven (2008) have provided empirical evidence supporting this theory, asserting that a marginal increase of a one-standard- deviation increase in the overall index of transport-related stocks would result in a corresponding rise of 2.9 percentage points in per capita income growth. According to Aschauer (1989) and Boopen (2006), an analogous augmentation in the road facility quality index would result in a growth enhancement of 0.68 percentage points. In order to enhance one's understanding of the impact of transportation infrastructure on a nation's economic growth. The implementation of any form of disorganized arrangement is likely to result in adverse consequences throughout several economic domains, encompassing both corporate and personal spheres. Hence, it is imperative for the government to acquire a comprehensive understanding of the implications associated with allocating resources towards the development of road transportation infrastructure in relation to economic progress. This understanding should encompass the determination of appropriate investment destinations, the optimal proportion of investment relative to the gross domestic product (GDP), and the potential ramifications of such investments on the nation's affluence and influence. As an illustration, it has been observed that several developing nations allocate approximately 2% of their gross domestic product (GDP) towards transportation infrastructure on an annual basis. In contrast, China has purportedly made a commitment to invest 7% of its GDP specifically towards the development of transportation infrastructure systems (Commission on Growth and Development [CGD], 2007).

Traffic Congestion and Transportation of Agricultural Products

The term "congestion" is commonly used in the context of road traffic, by both professionals and the general public. According to the definition provided in Webster's Third New International

Dictionary, congestion is characterized as a state of overcrowding or overburdening. Similarly, the verb "to congest" denotes the act of overcrowding, overburdening, or excessively filling anything to the extent that it obstructs or hinders, specifically in the context of road traffic. According to the Joint Transport Research Centre (2007) established by the Organization for Economics and Development (OECD) and the European Conference of Ministers of Transport (ECMT), traffic congestion can be described as the occurrence when the demand for road space surpasses its available supply.

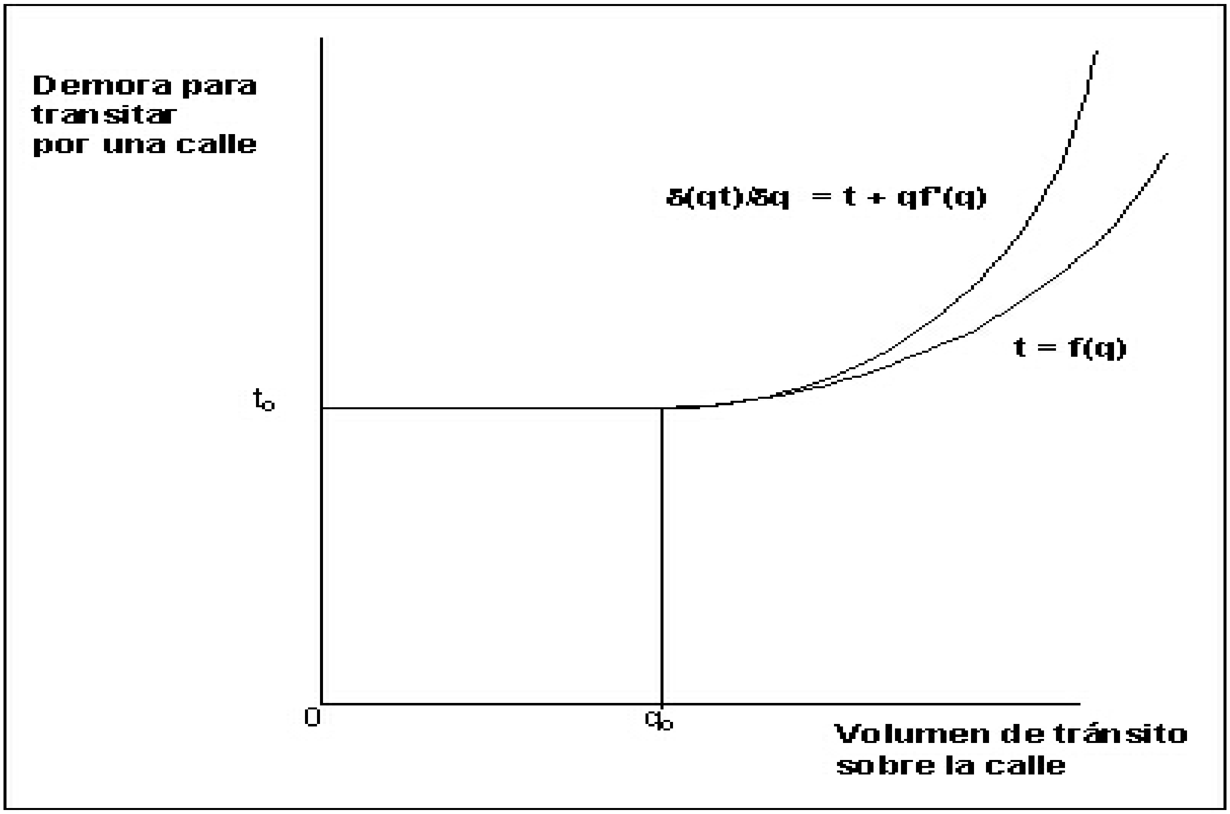
On the contrary, it is commonly interpreted as a scenario characterized by a substantial volume of cars in circulation, regardless of which are progressing in a sluggish and erratic manner. The aforementioned definitions possess a subjective quality and lack the necessary level of precision.

According to Hougendoorn and Bovy (2001) as well as the North County Times (2004), the issues of traffic flow, traffic increase, and congestion are significant economic and societal challenges associated with transportation in developed nations. The aforementioned issues are evident in several forms such as environmental pollution, delays, accidents, and land use severance (Ogunsanya, 2006). Ayeni (1983) previously articulated a similar perspective, noting that these issues represent a selection among the 18 most urgent and conspicuous urban challenges in Nigeria. According to Mabogunje (1974, as cited in Ayeni, 1992), a significant issue in urban areas is the concept of "livability," which is characterized by environmental deterioration, excessive burdens, and congestion.

According to Odeleye (2018), According to the source, the primary cause of urban congestion is attributed to the suboptimal utilization of road infrastructure. The issue of traffic congestion is exacerbated by several factors, including roadside and on-road parking, road-side trading, and the widespread non-compliance with traffic regulations exhibited by road users.

The primary factor contributing to congestion is the presence of friction or mutual interference among cars inside the traffic flow. Until a specific threshold of traffic volume is reached, vehicles have the ability to travel at a speed that is generally unconstrained and contingent upon factors such as the legally imposed speed limit, the density of intersections, and other contextual variables. At elevated levels of traffic data, however, the presence of each new car disrupts the flow of other vehicles, resulting in the occurrence of congestion. One potential objective definition, as proposed by Thomson and Bull (2001), is as follows: "Congestion refers to the circumstance in which the inclusion of an extra vehicle into a stream of traffic results in an increase in travel durations for the remaining vehicles."

As the volume of traffic rises, there is a corresponding decrease in traffic speeds, exhibiting a



progressively steeper decline. The function t = f(q) denotes the relationship between the time (t) required to traverse a street and the various types of traffic (q). The additional equation, d(qt)/dq = t + qf'(q), is obtained as a result of the derivation of the aforementioned function. The disparity across the two curves signifies the augmentation in the travel durations of the remaining cars in operation as a consequence of the inclusion of an extra vehicle, for any given traffic volume (q) (refer to Figure 1).

Figure 1: Schematic Representation of Traffic Congestion

It is worth mentioning that the two curves align until reaching a traffic level denoted as a until this threshold, the total journey time of all cars only increases by the time consumed by an extra vehicle, while the rest can keep circulating at their previous pace. Subsequently, the two functions deviate, and the derivative of q(t) with respect to q surpasses t. This implies that the introduction of each extra vehicle not only incurs delay for itself, but also contributes to the overall delay experienced by all other vehicles already in circulation. As a result, it can be observed that the average user possesses limited awareness regarding the extent of congestion they contribute to, with the remaining burden being borne by other vehicles within the current traffic flow (Ortúzar, 2014). Within the realm of specialized terminology, it is often acknowledged that users possess the ability to comprehend the average private costs, while remaining unaware of the marginal societal costs.

As per the previously provided definition, congestion initiates when the traffic level reaches Oq0. In general, it is important to note that this phenomenon typically takes place during periods of very low traffic volume, contrary to popular belief. Certain types of cars contribute to a higher level of traffic congestion compared to others. Within the field of transport engineering, it is customary to designate a numerical value known as a passenger car unit (PCU) to quantify the relative capacity of different types of vehicles. A private automobile is considered to be equivalent to one passenger car unit (pcu), whilst other types of vehicles are assigned equivalencies based on their impact on traffic flow or the amount of space they occupy in relation to a private car. In conventional terms, it is often accepted that a bus is deemed to possess a value equivalent to three passenger car units (PCUs), whereas a truck is assigned a value of two PCUs. From a technical standpoint, it is important to note that the pedestrian crossing utilization (PCU) factor exhibits variability based on the proximity of the vehicle to a junction or its location inside a road segment connecting two intersections.

Description of the Study Area

The research region encompasses the states of Ekiti, Ondo, and Osun, which are geographically located within the longitude range of 20°31' E to 60°001' E and the latitude range of 60°21' N to 80°371' N (Figure 1). The study area experiences two distinct seasons throughout the year, namely the rainy season (April-October) and the dry season (November-March). The temperature range in the given zone is between 21 to 28 degrees Celsius (0°C), accompanied by a rather high humidity level of 77 percent. Therefore, agricultural activities, including the cultivation of crops and rearing of livestock, are conducted with minimal challenges in the region. Agriculture constitutes the primary occupation of the local populace. Other vocations encompass several fields such as trading, driving, and carpentry, among others. Ondo state is geographically surrounded by Ekiti and Kogi states to the north, Edo state to the east, Ogun state to the west, and the Atlantic Ocean to the south. According to a source from www.onlinenigeria.com, the state of Osun exhibits a variation in average rainfall, with the derived savanna region experiencing an average of 1125 mm of rainfall, while the rainforest belt receives a higher average of 1475 mm. The average yearly temperature exhibits a variation, with December seeing a mean temperature of 39.0°C, while June has a lower mean temperature of 27.2°C. The relative humidity during the early morning hours consistently exhibits high levels, typically exceeding 90% throughout all seasons. The studied region is characterized by the presence of Precambrian rocks from the Basement Complex, which are occasionally covered by a variable thickness of overlying material (Rahaman, 1988). Ondo state is characterized by three distinct ecological zones: mangrove in the southern part, rainforest in the central part, and savannah in the northern part. The annual rainfall in Ondo state varies from 2000mm in the south to 1200mm in the north. In Osun state, the vegetation is classified as a lowland forest zone according to Keay (1959), semi-deciduous moist forests according to Charter (1969), Guineo-Congolian forest according to White (1983), and a dry forest sub-group according to Hall (1969). Ekiti state, on the other hand, is predominantly covered by rainforest vegetation, as described by the Ekiti state government (2016). The southern part of Ekiti state is distinguished by dense forests of evergreens with tall trees and thick vegetation, while the northern part is occupied by Guinea savannah forest.

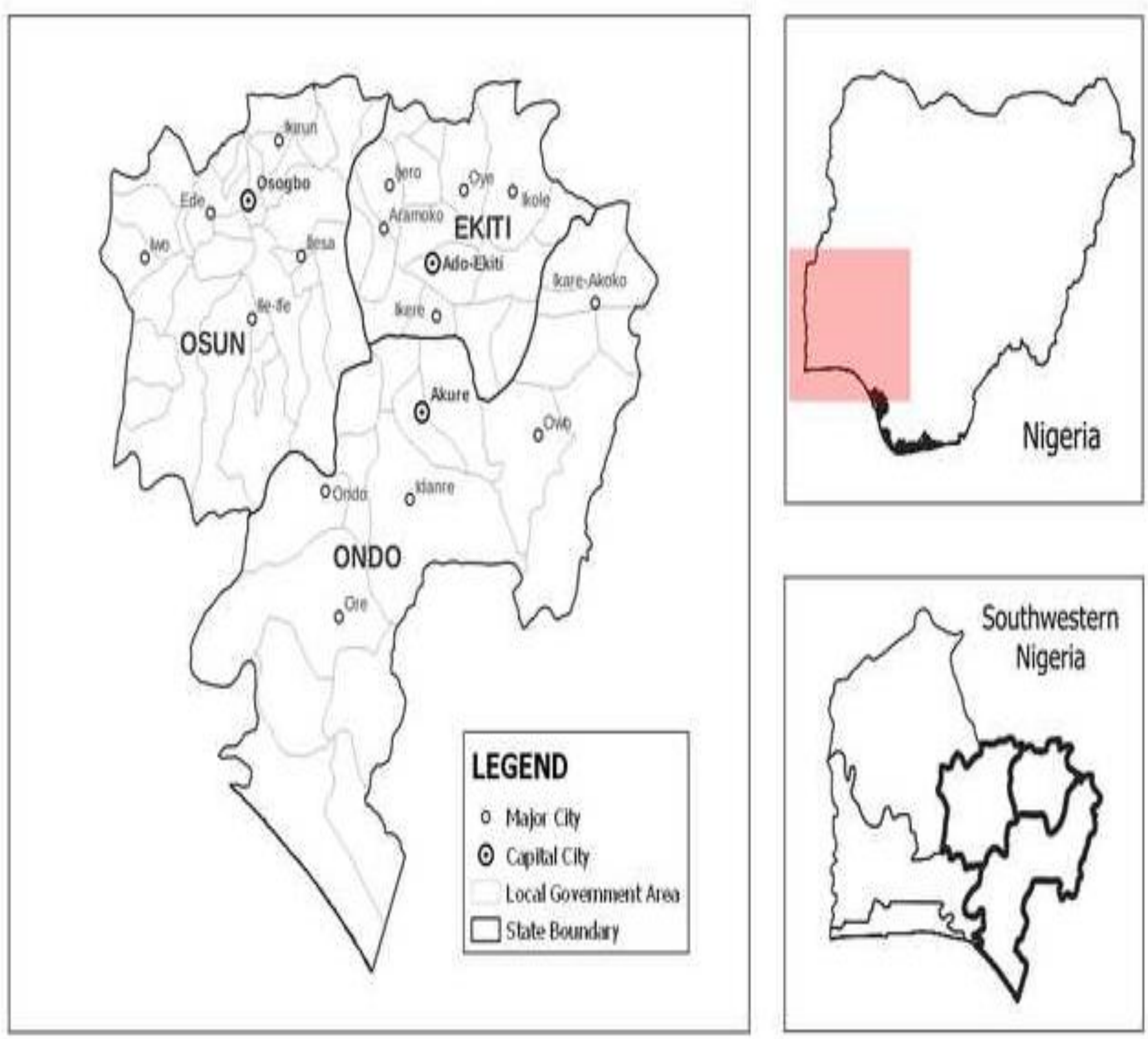


Figure 1: Study area states

Data Collection

The study employed a cross-sectional research design as it aimed to gather data from a diverse sample of individuals within the community at a particular point in time. The three research region states, namely Ondo, Osun, and Ekiti, were purposefully selected due to their comparable characteristics in cocoa and cassava production and commercialization. The collection of primary data was conducted by a field survey, in which copies of the survey instrument were sent to selected main markets in each state within the study area. Hence, a deliberate selection process was employed to identify a significant market within each senatorial district of every state. The data acquired from each major market are regarded to be reliable representations due to the challenges associated with examining the entirety of the key markets within the study area. The study relied on transporters and market participants as the key sources of data. A survey was conducted throughout the research region states, targeting transporters and market men and women. A total of 400 questionnaires were adminstered among individuals in the three major marketplaces. The questionnaire had a semi-structured format, consisting of Likert rating scales with response options ranging from "Strongly agree" (4) to "Strongly disagree" (1). This implies that participants were provided with the chance to indicate their levels of consent or disapproval on each specific statement. A total of 353 questionnaires were collected for the study, representing a response average of 90.7% out of the 400 adminstered.

Sampling Procedure

Random sampling method was used to ensuring equal opportunities for all individuals to be chosen as respondents in the study.

Data Analysis

Descriptive statistics were utilized to display the data in the study. The study's findings were visually represented through the use of tables and charts. The study employed regression analysis to investigate the presence of a statistically significant relationship amongst traffic congestion and transportation features of agricultural products within the designated study area. The questionnaires that were acquired were coded in an Excel spreadsheet and subsequently analyzed using the latest version of SPSS 25.0.

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Table 1**:** Effect of traffic congestion on transportation of agricultural products in Ondo State

S/N	**Prevalence of traffic congestion in transportation of agricultural products**	**Scale Rating**				**Mean**	**Rank**	**Remark**
		SD (1)	**D (2)**	**A (3)**	**SA (4)**			
1	There is an excessive presence of law enforcement officers and other armed forces personnel obstructing traffic on important roadways.	3	3	68	64	3.40	3rd	Agreed

2	The elevated occurrence of vehicle breakdowns can be attributed to the substandard condition of road infrastructure.	2	2	66	68	3.45	2nd	Agreed
3	The absence of obligations exhibited by operational staff member.	4	5	74	55	3.30	4th	Agreed
4	The inadequate state of road infrastructure is a significant factor contributing to the occurrence of traffic congestion in the transportation of agricultural goods.	1	2	66	69	3.46	1st	Agreed

Mean Criterion: Reject if mean score is less than 2.5

Table 2: Effect of traffic congestion on transportation of agricultural products in Osun State

S/N	**Prevalence of traffic congestion in transportation of agricultural products**	**Scale Rating**				**Mean**	**Rank**	**Remark**
		SD (1)	**D (2)**	**A (3)**	**SA (4)**			
1	There is an excessive presence of law enforcement officers and other armed forces personnel obstructing traffic on important roadways.	7	14	51	55	3.21	2nd	Agreed
2	The elevated occurrence of vehicle breakdowns can be attributed to the substandard condition of road infrastructure.	12	14	66	35	2.98	3rd	Agreed
3	The absence of obligations exhibited by operational staff member.	9	12	48	58	3.22	1st	Agreed
4	The inadequate state of road infrastructure is a significant factor contributing to the occurrence of traffic congestion in the transportation of agricultural goods.	12	14	66	35	2.98	3rd	Agreed

Mean criterion: Reject if mean score is less than 2.5

Table 3: Effect of traffic congestion on transportation of agricultural products in Ekiti State

S/N	Prevalence of traffic congestion in transportation of agricultural products	Scale Rating SD (1)	D (2)	A (3)	SA (4)	Mean	Rank	Remark
1	There is an excessive presence of law enforcement officers and other armed forces personnel obstructing traffic on important roadways.	13	13	36	26	2.85	1st	Agreed
2	The elevated occurrence of vehicle breakdowns can be attributed to the substandard condition of road infrastructure.	16	20	29	23	2.67	3rd	Agreed
3	The absence of obligations exhibited by operational staff member.	15	19	30	24	2.72	2nd	Agreed
4	The inadequate state of road infrastructure is a significant factor contributing to the occurrence of traffic congestion in the transportation of agricultural goods.	16	20	29	23	2.67	3rd	Agreed

Mean criterion: Reject if mean score is less than 2.5

Correlation between Traffic Congestion and Transportation of Agricultural Products

Table 4 presents the findings of the correlation analysis conducted to examine the relationship between traffic congestion and the transportation of agricultural products. The findings indicate a notable association (-0.864) and statistical significance ($p = 0.023$) between vehicle traffic and the delivery of agricultural products. This suggests that a rise in traffic congestion will result in a corresponding decline in the transportation of farm produce within the examined region.

Table 4: Correlation between traffic congestion and transportation of agricultural products in South West Nigeria

Correlations				
			Traffic congestion	Transportation of agricultural products
Spearman's rho	Traffic congestion	Correlation Coefficient	1	-.864**
		Sig. (2-tailed)	.	.023
		N	353	353
	Transportation of agricultural products	Correlation Coefficient	-.864**	1
		Sig. (2-tailed)	.023	.
		N	353	353

** Correlation is significant at the 0.05 level (2-tailed).

Conclusion and Recommendations

The study's findings indicate a notable correlation between traffic congestion and the transportation of farm produce within the designated study area. This finding aligns with the research conducted by Tunde and Adeniyi (2012), which demonstrated that road transit has both beneficial and detrimental effects on agriculture in Ilorin East, Kwara State. Furthermore, the adverse road conditions have had a detrimental impact on the transportation costs associated with agricultural produce, consequently influencing the revenue of rural farmers. The research findings indicate that traffic congestion significantly impedes the timely and successful distribution of farm produce within the specified geographical region. Based on the aforementioned findings, it is advisable that the government take action to dismantle the illicit roadblocks established by members of the Nigerian Police Service on roadways within the study area. Additionally, it is advised that comprehensive guidelines pertaining to the enhancement of freight movement along transportation routes are efficiently conveyed to traffic control departments and security entities, with the aim of addressing the problem of traffic congestion. Furthermore, it is suggested that the government undertake substantial road rehabilitation initiatives, as this will contribute to the amelioration of road conditions along transportation routes, thereby mitigating traffic congestion within the study area.

References

Aderamo AJ (2010) Operational Efficiency, Public Transport, Transport System, Kwara State

Aderamo AJ, and Magaji SA. (2010). Rural Transportation and the distribution of Public facilities in Nigeria: A case of Edu Local Government Area of Kwara State. *Journal of human ecology; 29*(3), 171-179.

Ajiboye, A.O.and Afolayan, O. (2009). The Impact of Transportation on Agricultural Production in a Developing Country: A case of kola nut production in Nigeria. *International Journal of Agricultural Economics and Rural Development*, 49-57.

Anita, I., Leif, S., Göran, B., and Stefan, G. (2003) Planning of the road transport system

Aschuer, D. (1989). Is Pub1ic Expenditure Productive? *Journal of Monetary Economics*, 23(2) 177-200.

Ayeni, B. (1983) The Development of an Urban Landuse Transport Model for Lagos. Nigeria Geographical Journal, 26 (1/2).

Ayeni, B. (1992) A Place for Everything. An Inaugural Lecture. Department of
Geography, Faculty of Social Sciences, University of Ibadan.

Akpoghomeh, O.S. (2012).The terror of Transport and the transportation of terror . An InauguralLecture, University of Port Harcourt. P. 3.

Beyzatlar, M. A., &Kustepeli, Y. (2011).Infrastructure economic growth and population density in Turkey. International Journal of Economic Sciences and Applied Research, 4(3), 39-57. usiness Studies, 2(2) PP 24-30.

Boopen, S. (2006). Transport infrastructure and economic growth: Evidence from Africa using dynamic panel estimates.The Empirical Economical Letters, 5(1).

Ellis S, and Hine J. (2003). Agricultural marketing and access to transport services. TRL Limited, World Bank, 2003.

Ellis S, and Hine, J. (1998). The provision of rural transport services sub-saharan African transport policy program. No 37 World Bank Washington DC Working paper. *Example. Ethiopian Journal of Environmental Studies and Management, 5(3).*

Hougendoorn, S.P. and Bovy, P.H.I. (2001) State of the Art of Vehicles Traffic Flow Modeling. Journal of System and Control Engineering, 215 (4), pp. 283 – 303.

Joint Transport research centre 2007 Macro-, Meso- And Micro-Infrastructure

Planning and Assessment Tools.

Kareem, T.S (2010). Distribution and Logistics Management.Ibadan Titles Publishers.

Keay, R. W. J. (1959). Vegetation map of Africa, south of the Tropic of Cancer : Explanatory notes. With French translation by A. Aubreville. London: Oxford University Press

Kim, K. and Shieh, O. Enhanced Preparedness for Tornadic Thunderstorms: Critical Considerations for Surface Transportation Managers. Presented at 93rd Annual Meeting of the Transportation Research Board, Washington, D.C., 2014.

Kiprono, P. & Matsumoto, T. (2014). Roads and farming: The effect of infrastructure improvement on agricultural input use, farm productivity and market participation in Kenya. In *CSAE conference 2014:* Economic development in Africa, The University of Oxford.

Kustepeli, Y., Gulcan, Y., &Akgungor, S. (2012). Transportation infrastructure investment growth and international trade in Turkey. *Applied Economics, 44*(20*), 2619-2629.*

Mabogunje, A.L. (1968) Urbanization in Nigeria, University of London Press Ltd.

Musa,A.(2008) Potentials of Rice Husk Ash for Soil Stabilization. Department of Civil Engineering, Federal University of Technology Minna, Niger State, Niger.A UJ.T. 11(4): 246-250 (Apr. 2008)

Musa, I.J. (2009). Role of transport in marketing and distribution of tomatoes in Nigeria. *Journal of Logistics and Transport, 1*(2), 9-12.

Njoh, A. J. (2012). Impact of transportation infrastructure on development in East Africa and the Indian Ocean region. *Journal of Urban Planning and Development, 138*(1)*,* 1-9.

Odeleye, A. T. (2018). Quality of Corporate Governance on Dividend Payouts: The Case of Nigeria. African Development Review, 30(1), 19-32.

Odusmosu, A,O.,Odeleye ,A,T., Bayero S,F.(2018)Advance in Transport Research in Nigeria by the Nigerian institute of transport Technology (NITT) penile Breakthrough prints Ibadan

Ogunsanya, A.A (2006) Transport Sector Reform: Principles and Practice. Paper presented at the CILT Conference on Transport Sector Reforms, Gateway Hotel, Otta, 8th – 9th, 2006.

Oni T.O. (2010). Ethno-botanical survey of fallow plot for medicinal plants diversity in Idena, Ijebu Ode. South Western Nigeria. Journal of Medicinal Plants Research,3. (10) 45-52

Ortiz R, Swennen R (2014) from crossbreeding to biotechnology-facilitated improvement Of banana and plantain. Biotechnol Adv 32:158–169

Rahaman, M.A. (1988) Recent Advances in the Study of the Basement Complex of Nigeria. In Precambrian Geology of Nigeria, Geological Survey of Nigeria, Kaduna South, 11-43.

Salisu .G. (2008) Road Transport Problems In Kanos Metropolis, Nigeria

Taafee EJ, Gauthier HL. Geography of transportation. 2nd ed. Upper saddle river New Jersey (USA): Prentice-Hall publishers; 1996.

Thomson l. and Bull. A (2001) Urban traffic congestion; lts economic and social causes and consequences, CEPAL I review 2002 (76); 105.116

Tunde,E and E. Adeniyi, (2016). Impact of Road Transport on Agricultural Development: A Nigerian Example. Ethiopian Journal of Environmental Studies and Management, Vol.5 (3): PP. 1-7.

White, F. (1983). The vegetation of Africa, a descriptive memoir to accompany the UNESCO/AETFAT/UNSO vegetation map of Africa. Paris: UNESCO.

EFFECTS OF FREIGHT RATES ON ROAD TRANSPORTATION OF AGRICULTURAL PRODUCT IN SOUTHWEST NIGERIA

Ajao Oluseyi Stephen,Chukwu-Okeah, G.O

Nigerian Institute of Transport Technology (NITT), Zaria

ajasent477@gmail.com, giftchukwuokeah@yahoo.com

Abstract

This study investigated the impact of freight rates on the transportation of farm produce through road in certain states located in the southwestern region of Nigeria. The study utilized a cross-sectional design. To collect data for the study, a survey consisting of 400 questionnaires was distributed among transporters and market sellers in the major markets of Ondo, Osun, and Ekiti states within the study area. Data presentation in this study involved the utilization of tables and charts, while the evaluation of the relationship amongst traffic congestion and agricultural product distribution features was conducted by regression analysis. The study's findings indicate that the supply of farm produce in the study area is adversely affected by fuel scarcity, high levels of extortion rates by customs, and long travel distances, which in turn lead to high freight rates. The research findings indicate that the delivery and distribution of farm produce in the study area are impacted by factors such as fuel scarcity, high extortion rates, and distance, which in turn affect freight rates. The study proposes, among other recommendations, the establishment of an agricultural output databank and storage facility in order to implement an environmentally conscious and efficient system to facilitate agricultural freight transportation in the study region.

Keywords: Freight Rates, Road Transportation, Agricultural Products

Introduction

According to Ojekunle's (2004) analysis of metropolitan freight flow in Nigeria, it was observed that the positioning of markets and industry serves as the determining factor for demand. Markets and manufacturing centers are significant hubs that generate and attract a substantial amount of freight. Due to the inherent characteristics of the items or commodities being transported, such as their weight, size, or perishability, it is imperative to ensure their efficient transfer from production areas to consumption areas, while minimizing delays, costs, and ensuring safety.

Hence, freight transportation serves as a catalyst for liberation, enabling the release of natural, man-made, and human resources from circumstances where their productivity and fulfillment are limited or nonexistent, and facilitating their transfer to locations where is maximum. Freight transportation encompasses the need to convey commodities from their point of origin to their intended destination, mostly through the utilization of transportation modes that are either owned or leased by the agency or client. The transportation of goods by freight is an indispensable component of contemporary urban society. According to Michael (2008), the presence of a dependable freight transport infrastructure is crucial for the functioning of any urban region.

According to Bayles (2000), the connection between manufacturers and markets, so facilitating individuals' access to employment, goods, services, and social possibilities. Various forms of transportation are employed for the purpose of transferring passengers, agricultural commodities, and manufactured items from areas of supply or production to regions of shortage or consumption located in different parts of Nigeria (Bamaiyi, 2011). According to Kotler and Armstrong (2006), marketing channels can be defined as a collection of autonomous entities that participate in the facilitation of product or service availability for consumption by consumers or business end users. The phrase "marketing channel" refers to the series of brokers or middlemen via which items are transferred from a manufacturer or farmer to the consumer.

Various constraints can impede the shipment and delivery of farm produce in the research area. These variables include fuel scarcity, delays caused by customs and security personnel, low demand, and geographical remoteness. Ajiboye (1994) posits that the presence of transportation infrastructure plays a pivotal role as an investment determinant, since it fosters economic growth by enhancing overall accessibility. According to Paul et al. (2009), the significance of road facilities on agricultural yields and efficiency in Sub-Saharan Africa can be attributed to three key factors. According to Paul et.al (2009), the agricultural sector plays a significant role in contributing to the gross domestic product (GDP) of the majority of Sub-Saharan countries. Furthermore, it is worth noting that poverty tends to be disproportionately concentrated in rural regions. In conclusion, the presence of inadequate road infrastructure and extended average trip durations contribute to elevated transaction expenses associated with the trade of agricultural both input and output. Consequently, this serves as a constraint on agricultural productivity and impairs its potential for expansion. Therefore, it is imperative to ensure that sufficient road infrastructure is established, fuel prices remain stable, concerns related to inflation impacting demand are managed, and issues contributing to prolonged travel time are effectively addressed. Therefore, it is essential to examine the characteristics of freight rates in connection with the transportation of agricultural products, namely in terms of load capacity measured in tonnes or kilos. Does the cost of shipping have any impact on the speed at which agricultural products are transported? What is the degree of association between freight charges and the transportation of grain and other agricultural products? The study investigates the impact of freight rates and road transportation on the movement of agricultural products in certain states located in the southwestern region of Nigeria, taking into consideration the aforementioned context.

Freight Rate and Transportation of Agricultural Products

Transportation, in various forms, is a fundamental and indispensable necessity for daily human endeavors, since it plays a crucial role in facilitating all human activities, including agriculture (Ademiluyi, 2006). Freight transportation is of paramount importance in facilitating the efficient functioning of any economy, particularly in cases where the road sector holds dominance. Agricultural operations, on the other hand, typically generate freight, which subsequently contributes to the overall economic prosperity of both developed and developing nations (Ojekunle, 2004).

Agricultural freight refers to the transportation of agricultural products from rural areas, such as farmlands, to various destinations including non-urbanized areas, marketplaces, city centers, and for international exports (Akangbe et al., 2013). This type of cargo primarily includes agricultural products such as food crops, cash crops, farm animals, poultry products, and perishable items like vegetables, tomatoes, peppers, and fruits. These goods are predominantly produced in rural areas at various levels of production (Omole & Owoeye, 2007). They are then transported to urban settlements, which serve as the primary market for these products due to their higher purchasing power. In relation to this matter, individuals residing in metropolitan places worldwide rely on farmers located in agricultural regions to fulfill their daily needs for agricultural commodities, which are utilized for consumption, industrial operations, and various other production endeavors (Taiwo, 2009). Therefore, it is imperative to ensure a smooth transportation of agricultural goods from rural areas to urban centers, since this is a crucial element in the everyday operation of the urban-rural system, essential for sustaining the human population.

The primary goal with regard to agricultural freight transportation is to efficiently fulfill the growing demand and supply of agricultural products while minimizing resource consumption, while also ensuring that both time and location utilities are not compromised. Therefore, by ensuring the efficient transportation of unprocessed products and finished goods in a timely, cost-effective, and secure manner, a robust and sustainable economic performance is assured. Furthermore, scholarly investigations conducted by the World Economic Forum (2015) and Napkhonenko et al. (2018) have examined and unveiled the significance of freight transportation in relation to both the well-being of humans and the natural environment, as well as the advancement of national progress and economic development.

Furthermore, following Nigeria's attainment of independence, there has been a predominant emphasis on investing in infrastructural facilities and formulating policies pertaining to the transportation industry, with a primary focus on facilitating passenger mobility. However, this approach has resulted in detrimental economic consequences due to the neglect of freight transportation. Infrastructural facilities have a crucial role in determining the competitive success of several sectors of the economy, including the agriculture sector. According to Fliehr (2013), the presence of efficient transportation infrastructure is essential for maintaining low transportation costs and ensuring international competitiveness. Conversely, a deficient infrastructure can result in increased transportation and logistics expenses, as well as congestion and longer delivery times during peak harvest seasons. In accordance with the findings of Caixeta-Filho (2013), it is evident that the presence and quality of transportation infrastructure play a crucial role in determining the competitive viability of agricultural firms, as well as the overall performance of the agricultural sector. Given the escalating food crises, adverse weather conditions, and infrastructure failures that are consistently ranked as prominent global risks, it is imperative to address these contemporary challenges. The primary objective is to mitigate these risks, minimize the socio-economic losses, and establish an effective framework for the transportation of agricultural freight.

According to Afolabi et al (2016), the significance of well-maintained rural-urban highways and efficient transportation methods for agricultural output cannot be overstated. These factors play a crucial role in promoting increased productivity, favorable pricing, and reduced transportation expenses. According to Musa et al. (2014), various transportation networks utilized for the transportation and distribution of agricultural produce encounter challenges that contribute to inefficiencies. These challenges include fluctuations in gasoline prices, delays and harassment by law enforcement, as well as factors such as inadequate transport infrastructure, multiple driver stopover locations, and mechanical issues primarily stemming from the aging of vehicles. These issues not only impede the distribution process but also result in damage, spoilage, and weight loss of agricultural commodities.

According to Napkhonenko et al. (2018), it has been determined that the transport services provided to companies and organizations inside agricultural and industrial complexes, as well as the harvesting-transportation-realization (HTS) complex, do not fulfill the current standards and expectations. Consequently, the rise in transportation expenses is transferred straight to the more vulnerable market participant, resulting in their inability to satisfy current demands. Therefore, the increase in transportation expenses has an impact on market prices. According to an investigation carried out by Zhao et al. (2019), it was shown that the implementation of time restrictions can lead to an increase in freight prices and a modest decrease in local emissions. On the other hand, the expansion of logistics infrastructure can result in an increase in both costs and greenhouse gas emissions.

Description of the Study Area

The geographical region comprises the states of Ekiti, Ondo, and Osun, which are located within the longitudinal coordinates of 20°31' E and 60°001' E, and the latitudinal coordinates of 60°21' N and 80°371' N (Figure 1). The study area experiences two distinct seasons throughout the year, namely the rainy period (April-October) and the dry season (November-March). The temperature range within the designated zone is from 21 to 28 degrees Celsius (0°C), accompanied by a rather high humidity level of 77 percent. Therefore, agricultural activities, including the cultivation of crops and rearing of livestock, are carried out with minimal challenges in the region. Agriculture constitutes the primary economic activity of the local population. Other vocations encompass several fields such as trading, driving, and carpentry, among others. Ondo state is geographically surrounded by Ekiti and Kogi states to the north, Edo state to the east, Ogun state to the west, and the Atlantic Ocean to the south. According to a source from www.onlinenigeria.com, the state of Osun exhibits a variation in average rainfall, with the derived savanna region experiencing an average of 1125 mm, while the rainforest belt receives a higher average of 1475 mm. The average yearly temperature exhibits a variation, with December seeing a mean temperature of 39.0°C, while June has a lower mean temperature of 27.2°C. The relative humidity during the early morning hours consistently exhibits high levels, typically exceeding 90% throughout all seasons. The studied region is characterized by the presence of Precambrian rocks from the Basement Complex, which are occasionally covered by a variable thickness of overlying material (Rahaman, 1988). Ondo state is characterized by three distinct ecological zones: mangrove in the southern part, rainforest in the central part, and savannah in the northern part. The annual rainfall in the state varies, ranging from 2000mm in the south to 1200mm in the north. In Osun state, the vegetation is classified as a lowland forest zone according to Keay (1959), semi-deciduous moist forests according to Charter (1969), Guineo-Congolian forest according to White (1983), and a dry forest sub-group according to Hall (1969). Ekiti state, on the other hand, is predominantly covered by rainforest vegetation, as described by the Ekiti state government (2016). The southern part of Ekiti state is describes by dense forests of evergreens with tall trees and thick vegetation.

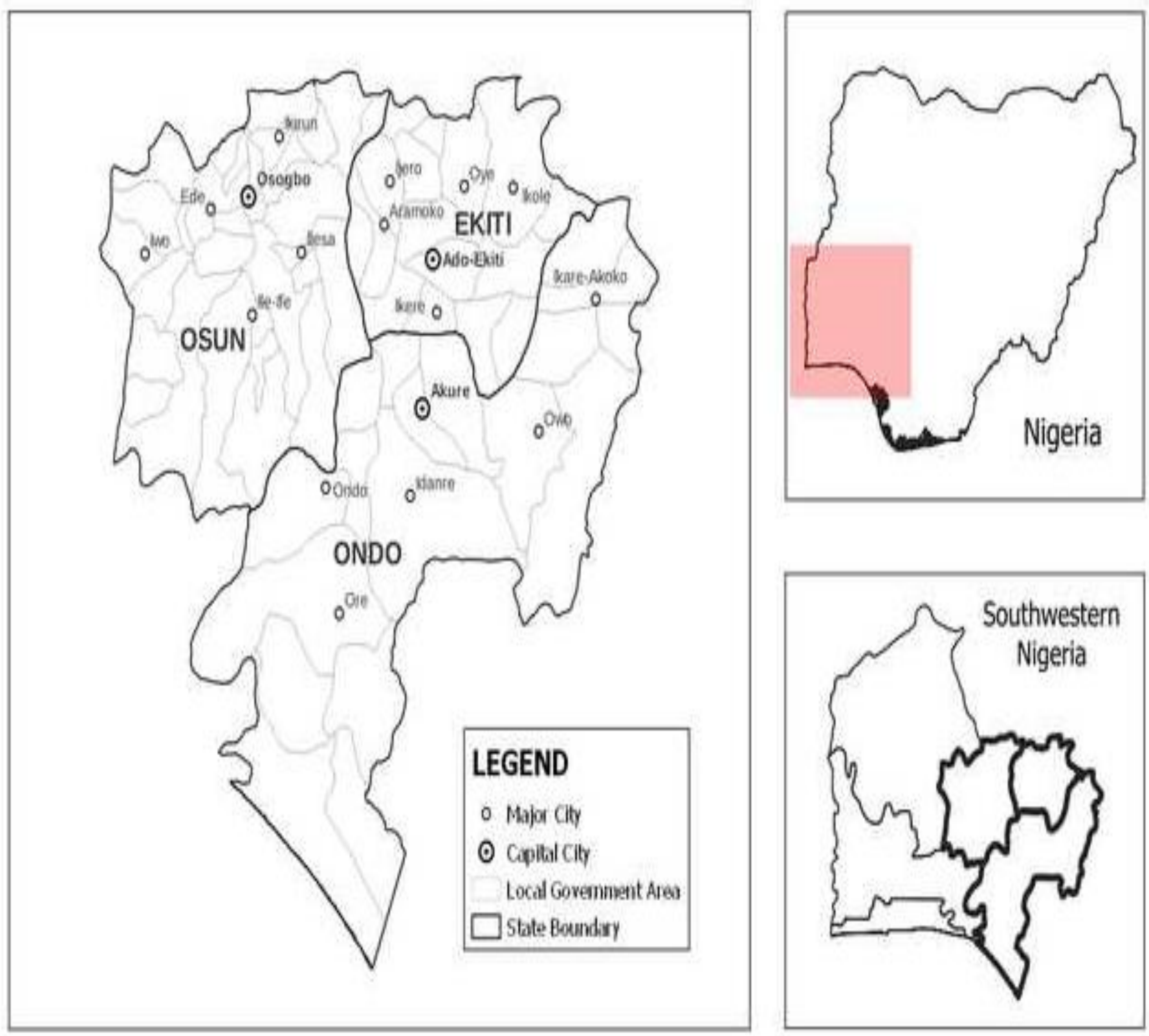


Figure 1: Study area Ondo, Osun and Ekiti states

Data Collection

The study employed a cross-sectional research design as it aimed to gather data from a diverse sample of individuals within the community at a particular point in time. The three research region states, namely Ondo, Osun, and Ekiti, were purposefully chosen due to their comparable characteristics in cocoa and cassava production and commercialization. The primary information was obtained by a field survey, in which copies of the survey instrument were sent to selected large markets in each state within the study area. Hence, a deliberate selection was made of a significant market inside each senatorial zone of every state. The data collected from each significant market are regarded as reliable representations due to the challenges associated with investigating all key markets within the study area. The study utilised transporters and market participants as the primary sources of data. A survey was conducted throughout the research region states, where a total of 400 questionnaires were distributed among carriers and market vendors. The questionnaire had a semi-structured style consisting of Likert rating scales, with response options ranging from highly agree (4) to agree (3), disagree (2), and mostly disagree (1). Participants were provided with the chance to indicate their levels of agreement or disagreement for each specific statement. A total of 353 questionnaires were collected for the study, representing a response rate of 90.7% out of the 400 distributed copies.

Sampling Procedure

The researchers employed the random sampling method to pick participants, so ensuring equal opportunities for all individuals to be chosen as responders in the study. The participants can be of either male or female gender.

Data Analysis

Descriptive statistics were used to display the data in the study. The data collected for the investigation were provided in tabular and graphical formats. The questionnaires that acquired were coded in an Excel spreadsheet from the year 2020 and subsequently analyzed using SPSS version 25.0.

Freight rates and Agricultural Products

Data presented in Table 1 illustrates the variability in freight rates for various agricultural products (measured in kilograms) across different transportation routes. Figure 1 presents data on the freight rate and corresponding tonnage. Figure 2 provides an overview of the agricultural products delivered from the northern region to the South West. Lastly, Figure 3 presents information on the relationship between the freight rate and the agricultural products being transported.

Table 1: Agricultural Commodities, Transportation Routes, and Freight Rates in Chosen States in the Southwest Region of Nigeria

Agricultural Products	Routes	Freight Rate (N)	Load (Kg)
Yam	Kano to Lagos, Osun, Ondo and Ekiti	800, 000	30,000

Beans	Kano to Lagos, Osun, Ondo and Ekiti	1, 600,000	60,000
Tomatoes	Kano to Lagos, Osun, Ondo and Ekiti	400,000	15,000
Onions	Kano to Lagos, Osun, Ondo and Ekiti	600,000	20,000
Rice	Kano to Lagos, Osun, Ondo and Ekiti	1,000,000	40,000
Carrot	Kano to Lagos, Osun, Ondo and Ekiti	1, 200, 000	50,000
Potato	Kano to Lagos, Osun, Ondo and Ekiti	1, 400, 000	55,000

Source: Market Women Association. 2023

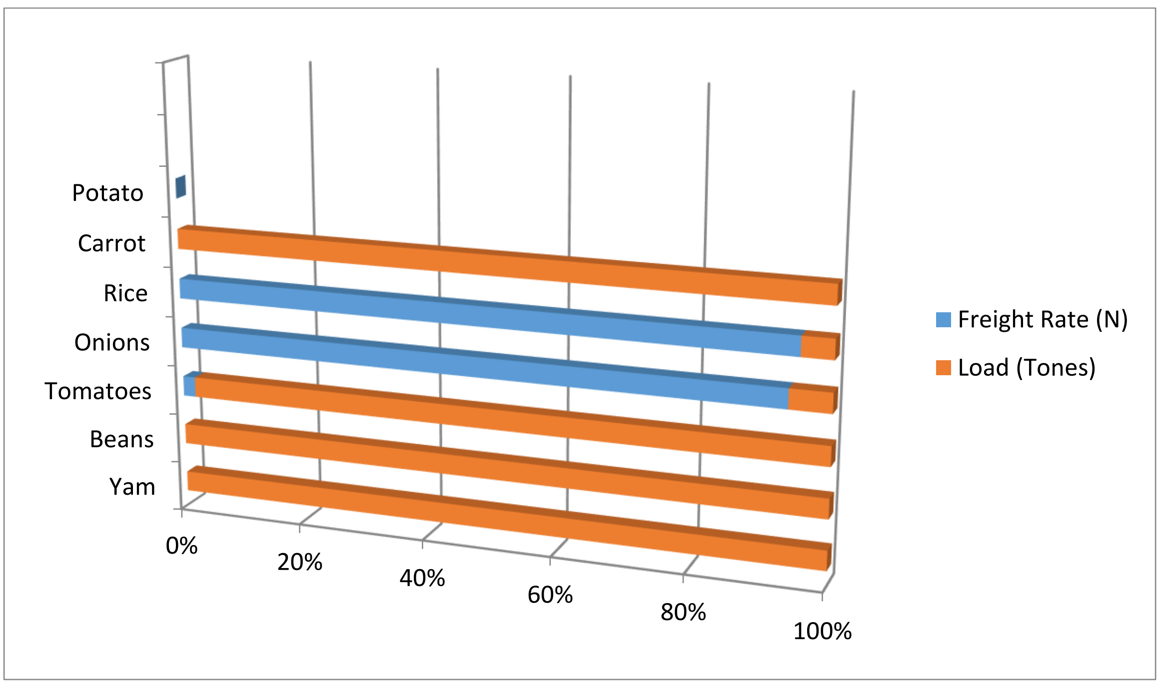


Figure 1: Agricultural products, Freight rate and No. of Tonnages

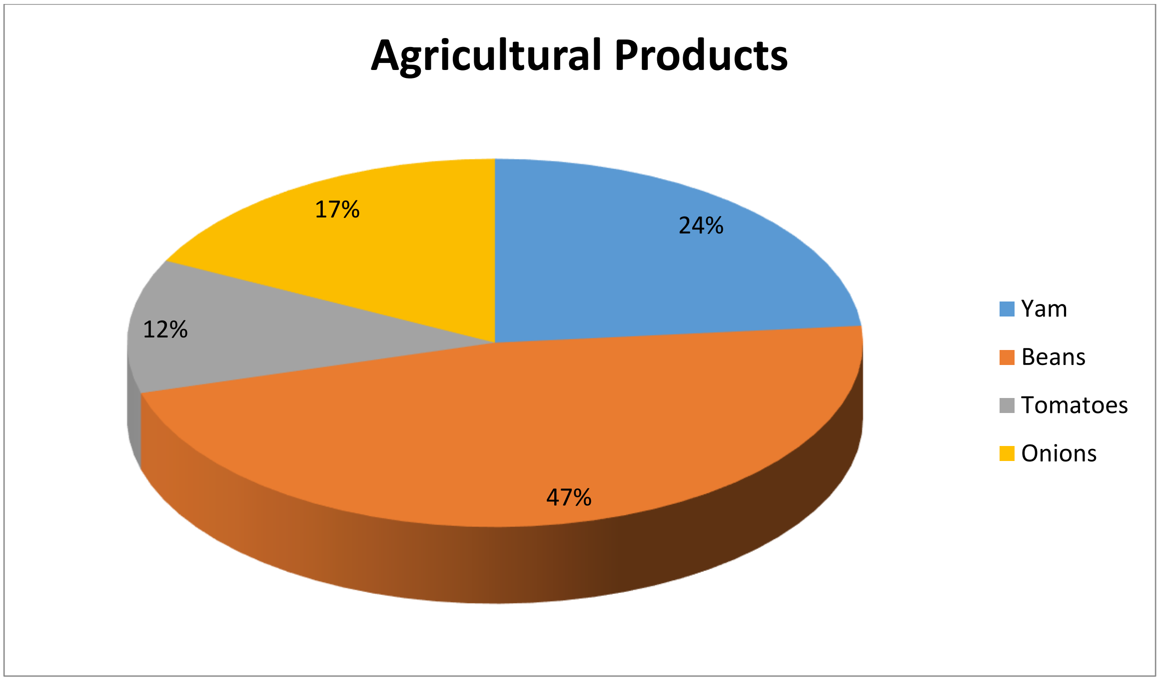


Figure 2: Agricultural products transported from the North to the Southwest

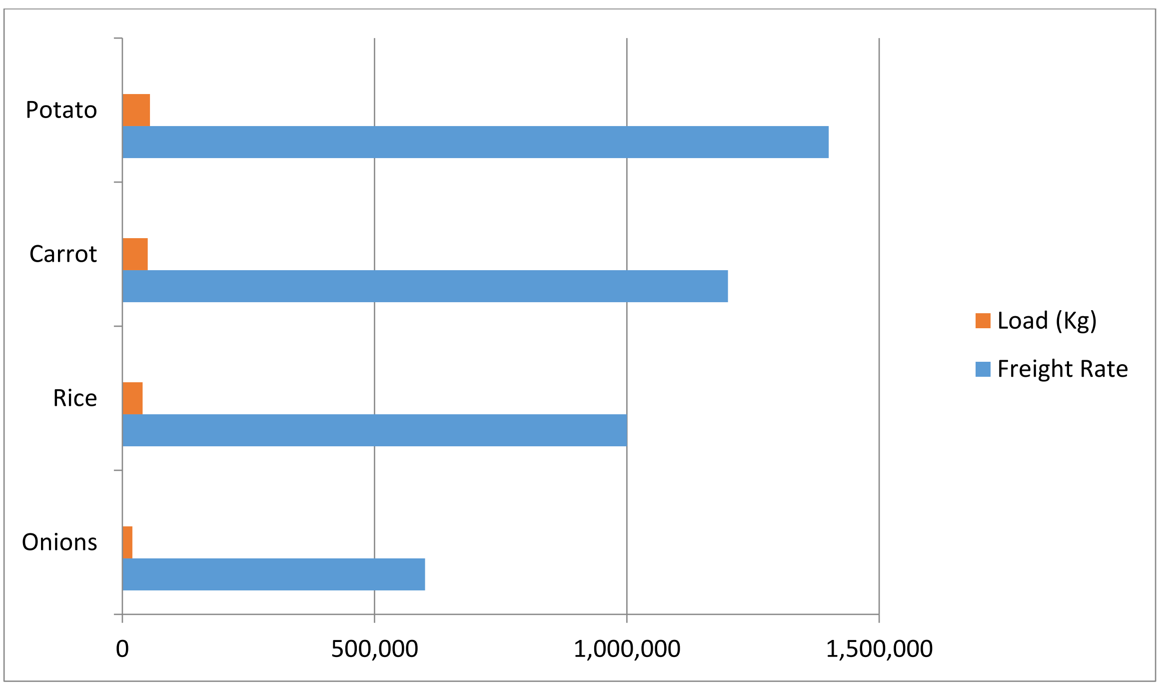


Figure 3: Freight rates, agricultural products and Weight (Kilogram)

Effect of Freight Rates on Transportation of Agricultural Products

The impact of freight rates on the transportation of agricultural products in Ondo State, Table 4.6 reveals that there is no corresponding indication of strong disagreement or disagreement among respondents on the assertion that the elevated levels of extortion by customs, police, and other armed forces significantly contribute to the high freight rates of farm products in the state. However, out of the total number of respondents, 60 individuals expressed agreement, while a majority of 78 respondents strongly agreed. This led to the acceptance of a mean score of 3.57, positioning it as the top-ranked response.

The second-ranked factor contributing to high freight charges of agricultural products is fuel scarcity. Out of the total sample size, 6 respondents expressed strong disagreement, 17 respondents expressed disagreement, 60 respondents expressed agreement, and 55 respondents expressed strong agreement.

The third-ranked factor in contributing to high freight rates is the distance traveled. Out of the total sample size of 138 respondents, 30 expressed strong disagreement, 32 expressed disagreement, 44 expressed agreement, and 32 expressed strong agreement. These responses yielded an average result of 2.57.

In contrast, a total of 42 participants expressed a strong disagreement with the notion that diminished product demand is a contributing factor to elevated freight rates for agricultural goods. The majority of respondents (79) likewise express disagreement with this statement.

According to the findings presented in Table 4.7, it was observed that in Osun state, the statement "High level of bribery by customs, police & other arm forces lead to high shipping costs rates of agricultural products" received varying degrees of agreement or disagreement from the respondents. The overwhelming majority of the participants (56) strongly agreed with the statement, while 49 respondents agreed with it. On the other hand, 10 respondents strongly disagreed and 12 respondents disagreed with the statement. These responses led to a mean score of 3.19 for the statement.

Eleven Out of the total sample size, 11 participants expressed severe disagreement, 12 participants expressed disagreement, 56 participants expressed agreement, and 48 participants expressed strong agreement with the statement "Fuel scarcity contributes to high freight rates of agricultural products." This data resulted in a mean score of 3.11 and a ranking of 2nd.

In response to the assertion that low product demand is a contributing factor to high freight charges of agricultural goods, a total of 14 respondents strongly disagreed, 44 respondents disagreed, 42 respondents agreed, and 27 respondents highly agreed. This data yields a mean score of 2.65, placing it in the third position in terms of ranking.

In relation to the assertion that "Distance travelled leads to high freight rates," it is worth noting that among the respondents, 36 strongly disagreed, 25 disagreed, 28 agreed, and 38 severely disagreed. Consequently, the mean score obtained was 2.54, placing this statement in 4th position in terms of ranking.

In the context of Ekiti State, the findings presented in Table 4.8 indicate that the impact of freight rates on the transportation of farm goods elicited various responses. Specifically, 15 respondents expressed strong disagreement, while 13 respondents disagreed. On the other hand, 27 respondents agreed, and thirty-three participants strongly agreed that fuel scarcity is a contributing factor to the high freight rates associated with agricultural products. Consequently, these responses yielded a mean score of 2.89, positioning it as the highest ranked factor.

The prevalence of bribery by customs, police, and other armed forces significantly contributes to the elevated freight prices of agricultural products, ranking second on the list. Out of the total respondents, 19 strongly disagreed, 17 disagreed, 24 agreed, and 28 strongly agreed with this statement, resulting in a mean score of 2.69.

The factor of distance travelled is ranked third in terms of its contribution to high freight rates. This ranking is based on the responses of 23 participants who strongly disagreed, 17 participants who disagreed, 20 participants who agreed, and 28 participants who highly agreed. The mean score of 2.60 indicates an overall acceptance of this factor's influence. Nineteen (19) participants express a significant dissent with the notion that reduced product demand is a contributing factor to elevated freight charges for agricultural goods. A total of 69 respondents participated in the survey, providing their opinions on the given statement. Among them, 23 respondents expressed disagreement, while an equal number of 23 respondents expressed agreement. Additionally, 23 respondents strongly agreed with the statement. The collective responses resulted in a mean score of 2.57, placing the statement in the fourth position in terms of ranking.

Table 2: Effect of freight rate on transportation of agricultural products in Ondo State.

S/N	**Effect of freight rate on transportation of agricultural products**	**Scale Rating**				**Mean**	**Rank**	**Remark**
		SD (1)	**D (2)**	**A (3)**	**SA (4)**			
1	The scarcity of fuel is a contributing factor to the elevated freight charges observed in the transportation of agricultural products.	6	17	60	55	3.19	2nd	Agreed
2	The correlation between reduced product demand and elevated freight rates for agricultural goods is a contributing factor.	42	79	9	8	1.88	4th	Disagreed
3	The exorbitant freight charges of agricultural products can be	0	0	60	78	3.57	1st	Agreed

	attributed to the pervasive presence of extortion within customs, police, and other armed services.							
4	The distance covered during transportation significantly influences the freight rate	30	32	44	32	2.57	3rd	Agreed

Mean criterion: Reject if mean score is less than 2.5

Table 2: Effect of freight rate on transportation of agricultural products in Osun State.

S/N	**Effect of freight rate on transportation of agricultural products**	**Scale Rating**				**Mean**	**Rank**	**Remark**
		SD (1)	**D (2)**	**A (3)**	**SA (4)**			
1	The scarcity of fuel is a contributing factor to the elevated freight charges observed in the transportation of agricultural products.	11	12	56	48	3.11	2nd	Agreed
2	The correlation between reduced product demand and elevated freight rates for agricultural goods is a contributing factor.	14	44	42	27	2.65	3rd	Agreed

3	The exorbitant freight charges of agricultural products can be attributed to the pervasive presence of extortion within customs, police, and other armed services.	10	12	49	56	3.19	1st	Agreed
4	The distance covered during transportation significantly influences the freight rate	36	25	28	38	2.54	4th	Agreed

Mean criterion: Reject if mean score is less than 2.5

Table 3: Effect of freight rate on transportation of agricultural products in Ekiti State

S/N	**Effect of freight rate on transportation of agricultural products**	**Scale Rating**				**Mean**	**Rank**	**Remark**
		SD	**D**	**A**	**SA**			
		(1)	**(2)**	**(3)**	**(4)**			
1	The scarcity of fuel is a contributing factor to the elevated freight charges observed in the transportation of agricultural products.	15	13	27	33	2.89	1st	Agreed
2	The correlation between reduced product demand and elevated freight rates for agricultural goods is a contributing factor.	19	23	23	23	2.57	4th	Agreed
3	The exorbitant freight charges of agricultural products can be attributed to the pervasive presence of extortion within customs, police, and other armed services.	19	17	24	28	2.69	2nd	Agreed
4	The distance covered during transportation significantly influences the freight rate	23	17	20	28	2.60	3rd	Agreed

Mean criterion: Reject if mean score is less than 2.5

Discussion, Conclusion and Recommendations

The study's findings indicate that the transportation of farm produce is significantly affected by freight charges, which are elevated due to the excessive extortion practices by customs, police, and other armed forces. This observation aligns with the research conducted by Salisu et al. (2020), which demonstrated that the prices of agricultural products and manufactured goods have significantly increased compared to the period of conflict. Additionally, the study highlighted the overlooked nature of the agricultural freight sector, emphasizing its substantial impact on the accessibility and affordable urban well-being. The study's findings indicate that agricultural freight transportation is characterized by significant deficiencies and inefficiencies, resulting in a negative impact on farmers' profitability. The study's findings indicate also that the imposition of freight rates negatively impacts the efficiency and effectiveness of agricultural product distribution throughout the Ondo,Osun and Ekiti states. Based on the aforementioned findings, the study proposes the implementation of a farm product databank and storage facility in order to establish an environmentally friendly plan and efficient system to facilitate agricultural freight transportation within the study area and the country. Additionally, it suggests that addressing corrupt practices within customs, which hinder the movement of goods, should be a priority for lawmakers in order to mitigate traffic congestion and the subsequent increase in freight rates. Moreover, the study recommends that the government undertake substantial road rehabilitation projects to enhance the condition of roads along transport routes, thereby alleviating traffic congestion and reducing freight rates in the study area.

Reference

Ajiboye, A.O (1994), Rural Accessibility and Transportation Problems. A case study of Ijebu North Local Governemnt Area,Ogun State. Unpublished PGD in Transport Thesis, Department of Geography and Regional Planning, Ogun State University, Ago-Iwoye.

Afolabi, O. J., Ademiluyi, I. A., &Oyetubo, A. O. (2016).Analysis of Rural Transportation of Agricultural Produce in Ijebu North Local Government Area of Ogun State Nigeria. *International Journal Economics and Management Science 6*, 1-6.

Ademiluyi, I. A. (2006). Historical evolutions and characteristics of transport modes in Nigeria. Babcock Journal of Management and Social Sciences, Vol. 5 No 1, pp. 91-109.

Akangbe, J.A., Oloruntoba, O.O., Achem, B. & Komolafe, S.E. (2013). An Appraisal of Transportation Facilities Effects on Agricultural Development in Moro Local Government

Area, Kwara Estate, Nigeria. *Ethiopian Journal of Environmental Studies and Management*. 6(2), 191–200.

Bamaiyi, H.H.(2011) An Analysis of the Problems Associated with Interregional Movements of Agricultural Commodities from Zaria. Unpublished Msc Thesis, Dept. of Geography, Ahmadu Bello University, Zaria

Bayles D.L. (2000) E- commerce Logistics and Fulfilment: Delivering the Goods. Prentice Hall. New York. Pp 11-32

Caixeta-Filho, J. V. (2013). Transportation and logistics in Brazilian agriculture, Delivered at the Agricultural Outlook Forum, February 20, 2013

Filani, M.O. (2005): "Rail Transportation as a Mechanism for Sustainable Economic Development of a Nation". Ago-Iwoye Journal of Social and Behavioural Sciences. (1) (1), Pp. 4-10.

Fliehr, Olivia. 2013. Analysis of Transportation and Logistics Processes for Soybeans in Brazil: A Case Study of Selected Production Regions. Thünen Working Paper 4. Braunschweig, Germany: Thünen Institute of Farm Economics. http://www.agribenchmark. org/fileadmin/Dateiablage/B-Cash-Crop/Misc/TLCSoybeansBrazil-Fliehr.pdf

Hall, R,(1969) The Hidden Dimension Handbook for Proxemic Research

Hesse, M. & Rodrigue, J.P (2004). The Transport geography of logistics freight distribution. Journal of Transport Geography. 2 (1) 171-184

Kandiero, T. (2009). Infrastructure Investment in Africa: Developement Research Brief Number *10*. African Development Bank (AFDB).

Kiprono, P. & Matsumoto, T. (2014). Roads and farming: The effect of infrastructure improvement on agricultural input use, farm productivity and market participation in Kenya. In *CSAE conference 2014:* Economic development in Africa, The University of Oxford.

Masugari, D Y,(2011) Freight Transportation Flow Of Agro-Based Commodities From Kaduna State, Nigeria

Michael, G.U. (2008). Freight flow pattern of agricultural commodities in Zaria Urban Area. A case study of Giwa and Maigana Markets. An unpublished final year project Ahmadu Bello University, Zaria.

Musa YN, Reuben J and Magaji IY. (2013). Problems associated with agricultural produce marketing in Nigeria: the experience of milled rice woman marketers from Southern Taraba State, Nigeria. *Research Journal of Agricultural and Environmental management 2*(1), 022-026.

Napkhonenko, N., Zagirniak, D. & Karaeva, M. (2018). Agricultural cargo transportation logistics system development. International Journal of Engineering & Technology, Vol. 7 No 4 & 3, pp.185-19

Ola, D.K (1978). Inter-regional marketing of agricultural products. Heineinann Educational books (Nig)) limited

Ojekunle, J. (2004). Urban freight Transportation in Nigeria. NITT Perspectives. Journal published

Onokala, P.C. (1988). The role of transportation in economic development in Nigeria. A case study of development of the rural transportation system and agricultural project in Imo state in Salau and Izeogu (eds) Development and the Nigerian Rural Environment. Proceedings of 31st annual conference of Nigerian geographical association.

Omole, F. K. & Owoeye, J. O. (2007). Inter-market transportation and patronage in Osun State, Nigeria. International Journal of Transportation Studies, Vol. 3 No 1, pp. 57-67

Paul.D, Hyoung-Gun.W, Liang.Y, and Emily.S (2009) Crop Production and Road Connectivity in Sub-Saharan Africa: A Spatial Analysis. Africa Infrastructure Country Diagnostic Working Paper 19. A publication of the World Bank.

Salisu, U.O. (2019). State of transport administrative structure in Lagos, Ogun, and Oyo States, Nigeria. Journal of Spatial and Organizational Dynamics JSOD, Vol. 7 No 1, pp. 68-85ii

Taiwo, K. A. (2009). The Global Food Crisis and the African Women Farmers in proceedings of 3rd International Conference of West African Society of Agricultural Engineers and 9th International Conference of Nigerian Institute of Agricultural Engineers held sat Obafemi Awolowo University, Ile-Ife, Nigeria on January 25-29, pg. 307-318

Tunde, A.M and Adeniyi, E.E.(2 012) Impact of Road Transport on Agricultural Development: A Nigerian Example Received 9th March 2012; accepted 24th April 2012.

Zhao, Y., Luo, Z.J., Y., Li, Y.T. et al. (2019) Research on Rural Residential Area Layout Optimization Based on Spatial Combination Characteristics. Transactions of the Chinese Society of Agricultural Engineering, 35, 265-272+31

INSTITUTIONAL INTERVENTIONS AND CONSTRAINTS ON CLIMATE CHANGE INDUCED REFUGEES

COOKEY, A.T. AND UNAEZE, H.C.

Department of Agriculture Economics and Agribusiness Management

University of Port Harcourt

E.Mail: cookeytammy@gmail.com

ABSTRACT

The study was conducted to analyze the Intervention rate and constraints between Institutions on Climate Refugees in Orashi, Niger Delta. The Objectives of the study were; to ascertain the difference of intervention between public and non-governmental Organizations on climate refugees and to identify the constraints encountered by institutions and the respondents in the study area, The hypothesis postulated for the study was There is no significant difference in the difference of intervention between public and Non-governmental institutions in the study area. Data were collected using Cross Tabulation and Descriptive statistics and the Student T-test was used to present and analyze the data. The findings revealed that on the difference of intervention between public and non-governmental organizations on climate refugees, the respondents received stimulus packages, training, and incentives more from governmental organizations than non-governmental organizations, going further 99% of the climate refugees opined that Insecurity and poor coordination of activities were major constraints encountered by them. Furthermore, the Student T test analysis proved that there is a statistically significant difference between the means of governmental organizations and Non-governmental Organizations at a 95% confidence level. It was recommended that Institutions should provide options and the autonomy to choose whether and where they will be relocated is essential to realizing ethically acceptable responses and the Government should design a multi-sectorial approach so as to build the capacity of Institutions in order to address the issue of climate refugees.

Keywords: Climate Change, Refugees, Institutional Interventions.

INTRODUCTION

As in the rest of the world, the impact of climate change on farmers resulting in low agricultural productivity is unlikely to abate anytime soon in West Africa. It is becoming a defining crisis of our time and disaster displacement is one of its most devastating consequences (United Nations High Commission for Refugees, 2021). An estimated 38 million people worldwide are forcefully displaced within the boundaries of their own country (World Bank, 2020). In the majority of cases, internally displaced persons (IDPs) live in protracted displacement, for IDPs fleeing rural areas, loss of land, productive assets, and sudden shift towards an agricultural lifestyle can be stagnating.

According to Onoja (2014) in his work on the effect of climate on arable crop farmer's productivity, food security and adaptation strategies in Nigeria noted that the vulnerability of the Nigerian agricultural sector to climate change is of particular interest to policymakers because agriculture is a key sector in the economy accounting for between 60 -70 percent of the labor force and contributing between 30-40 percent of the nation's Gross Domestic Product. For years, farmers who were affected by climate change in Nigeria were unable to produce their own food and relied solely on irregular and insufficient institutional/humanitarian aid for survival (Dissanyake, Mikunthan & Racioppi 2020).

Climate change alters habitats and disrupts ecosystems. Displacement due to climate change is also common in other species including mammals, birds, and amphibians. It was found that about 3,000 species were forced to move for survival in response to climate change (Nunez, Lawler, McRae & Tweeksbury, 2013). Similarly, humans are also subject to migration following the impacts of climate change that have impacted their livelihoods, homestead, or family members. Interestingly, uprooted mammals, birds, fish, and amphibians due to climate change are free to relocate or move anywhere, however, humans are not (Ahmed, 2017).

In recent times, Orashi, Niger Delta Region has witnessed an increasing incidence of forced displacement mainly caused by Climatic factors and this have drawn attention to the growing danger of displacement as being capable of reversing the strides towards achieving a reasonable standard of living for all people and of reversing the gains of developmental effort. These climatic factors have now become a serious environmental threat to the Niger Delta Region in general and has led to a large number of climate refugees often known as Environmental Migrants from the affected areas thus propelling institution to intervene so as to ameliorate the plight of these Climate refugees.

These Climate Refugees who are from agrarian communities in the state prefer camps hosted by institutions either government or Non-governmental organization who most times provide some level of humanitarian support to them, although they have been arguments that International and local institutions have falling far short of what is required however these various institutions play a major role as much as possible to offer stable support though it is unlikely that the refugees have been able to fully go back to their source of livelihood.

According to Unaze and Okoye (2016) these institutions are humanly created formal and informal mechanism that shape social and individual expectations, interactions, and behavior and can be classified as public, civic and private sectors.

The plight of these climate refugees has in recent years become a formidable problem of global significance and implications. Estimates and predictions of people displaced by environmental changes have been highly instrumental in the ever-increasing attention given to environmental migration in the media. Yet no consensual estimate exists. However, the question is how well is well with this migration of these refugees? In view of these mirages of challenges, there is a Nigeria Regional Refugee Response Plan which is aimed at mobilizing support for the inter-agency response to the refugee situation.

In the absence of a legal framework or institution, provision of assistance, protection, reintegration and resettlement for these climate refugees is mostly undertaken by institutions of government on an ad hoc and reactive basis. The draft National Policy aims to guide the different branches of government and humanitarian institutions in preventing displacement and in providing protection and assistance to those displaced. It also allocates responsibilities to the appropriate government bodies for different aspects of the short-, medium- and long-term response to internal displacement, with the existing National Commission for Refugees (NCFR) as the governmental focal point with responsibility for coordinating the activities of all agencies, including international humanitarian agencies. Furthermore, it empowers the National Emergency Management Agency, the Human Rights Commission and the Institute of Peace and Conflict Resolution to partner with the NCFR to support the activities of the states and local governments in implementing the Policy within their respective spheres of activities when it is officially launched.

Without a legal instrument in place and recognition of climate-affected people as refugees, the large body of climate-induced forcibly displaced people will deteriorate even further. It is therefore about time that the global community take action to address climate change and recognize “climate refugees” by placing it in a legal framework.

It is against these backgrounds that this paper tends to analyze the Intervention and Constraints between Institutions on climate Refugees in Orashi, Niger Delta Region

OBJECTIVES OF THE STUDY

The Specific Objectives of the study are to:

(i) Ascertain the rate of intervention between public and non-governmental Organizations on climate refuges in the study area.

(ii) identify the constraints encountered by institutions and the respondents in the study area

HYPOTHESIS OF THE STUDY

The following hypothesis was formulated to guide the study

$H_{01:}$ There is no significant difference in the rate of intervention between public and Non-governmental institutions in the study area

METHODOLOGY

Study Area

Orashi in the Niger Delta region of Nigeria, and conservatively covers an approximate landmass of 70,000km2 which represents one of the most extensive wetlands globally. It is an ecological zone located between latitude 4º and 6º North of the equator and longitude 5º and 7º East of Greenwich. It is also located on a coastal plain with fluvial deposits traversed by a number of rivers and tributaries which makes the area vulnerable to climatic factors (Mmom and Aifesehi, 2013). Orashi in the Niger Delta region consists of four ecological zones; lowland rainforest, freshwater swamp forests, mangroves and coastal barrier islands. It has dry and wet seasons, with poorly drained low-lying terrain and soil that encourages erosion and flooding occasioned by intense precipitation and river discharge in the wet season (Brown and Brisibe 2020).

As a region, it comprises of four local government areas; Abua/Odual, Ahoada East, Ahoada West and Ogba/Egbema/Ndoniwith six distinct ethnic nationalities; Abua, Egi, Ekpeye, Engenni, Kugbo, and Odual with diverse social, cultural, economic and political orientations. For ease of access and coordination of the research, each of the four local government area represents a case study site. According to the 2006 national population commission census records, the region has a combined population of 983,170 persons (NPC 2006) who are predominantly agrarian and subsistence fisher folks.

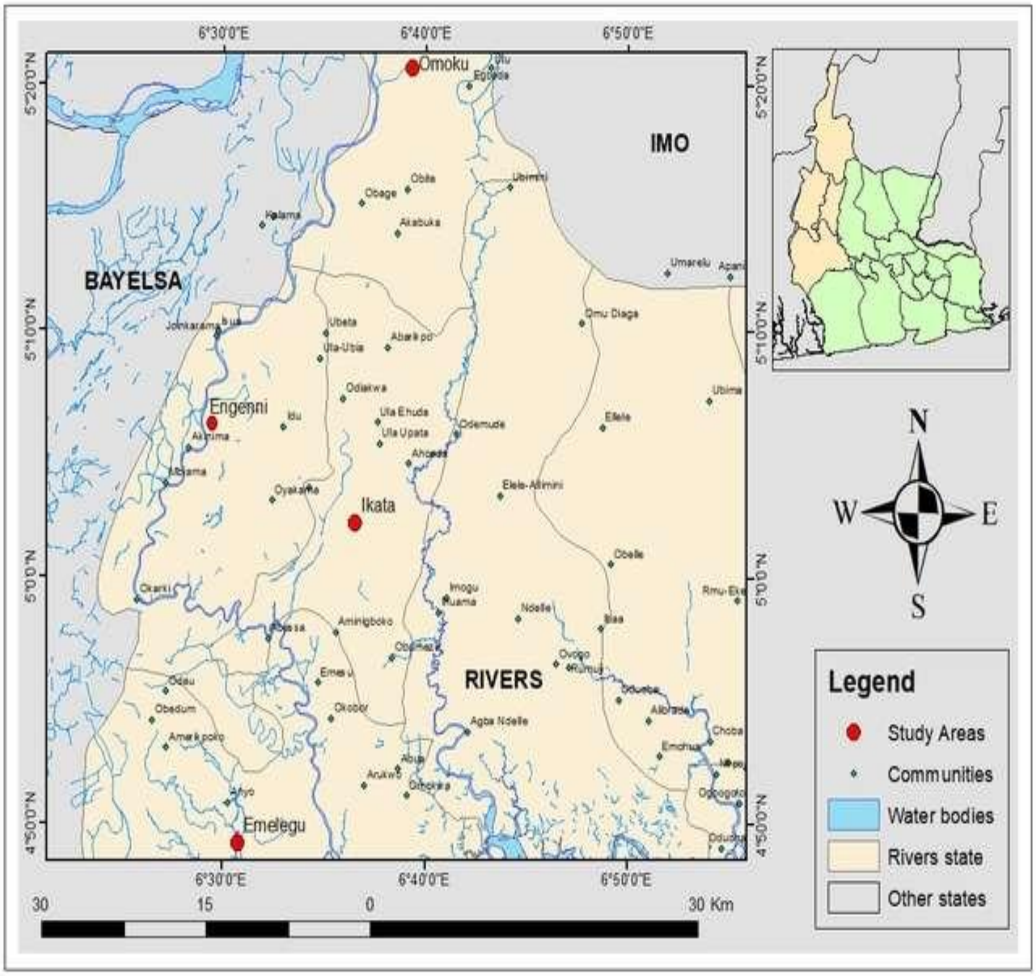


Figure 1: Orashi region showing the proposed sampled communities

Source: Rivers state Surveyor General Office, 2016

Population of Study

The Study population as seen in Table 1 was 155,000 persons (NEMA, 2021) which consisted of Individuals displaced by climate change in the selected four Local government areas of Orashi Region. These were local government areas affected by climatic variables.

Table 1: Climate Refugees and Sample Size Determination for the Study

S/N	Local Government Area	Number of Persons affected	Determination of Sample Size purposively
1	Ahoada West	54,000	25
2	Abua	46,000	25
3	Ahoada East	32,000	25
4	Ogba Egbema Ndoni	23,000	25
	Total	**155,000**	**100**

Source: National Emergency Management Agency 2021

Source: National Emergency Management Agency 2021

Sample Size and Sampling Technique

A total of one hundred (100) climate refugees were sampled using the Stratified random sampling technique . The Justification behind its use was that it helped to focus in-depth and on particular characteristics of a population that are of interest

For the Institutions, Purposive sampling procedure was also adopted in selecting thirty (30) Institution

The Justification behind the use of this procedure is that the process helped in selecting participants possessing characteristics associated with the research study.

Furthermore the rationale behind the selection of the L.G.A's was as a result of the Reconnaisance survey carried out by the researcher before the commencement of the research which indicated that the L.G.A's have been impacted by Climate change.

Sources of Data

Data for this work was from both primary and secondary sources. The primary data were obtained by administering copies of questionnaire and conducting interviews where needed, while the secondary sources of data were text books, serials, journals, internet sources and any other relevant sources.

Method of Data Collection

The instrument adopted for data collection for this study was the structured questionnaire and interviews. The structured questionnaire was designed to collect information on ascertaining the rate of intervention between public and non-governmental Organizations on climate refugees in the study area and identifying the constraints encountered by institutions and the respondents in the study area. Apart from the questionnaire the method of observation was adopted which helped in firsthand experience allowing the researcher to be open to discovery and inductive, rather than guessing what the content is. Observation will be used to learn things that people may be unwilling to discuss in an interview

Method of Data Analysis

Cross Tabulation and Descriptive Statistics such as frequency, mean and percentage was used whereas the *t*-test statistical analysis was used to compare the averages of the Public and Non-governmental Institutions and determine if the differences between them more are likely to arise from random chance

$$t = \frac{\bar{x}_{diff} - 0}{s_{diff}/\sqrt{n}} \qquad \text{.. 1}$$

RESULT AND DISCUSSION

Objective 1: Difference of Intervention between Public and Non-governmental Organizations on Climate Refugees

Table 2: Distribution of the Intervention between Public and Non-Governmental Organization on Climate Refugees

Intervention and Stimulus Package Received	Government Institution	Non-Governmental Institution

	Frequency	Percentage%	Frequency	Percentage%	Total
Provision of Tents, Mattresses, and Blankets	43	12	17	5	60(17)
Provision of Health care service delivery	25	7	22	6	47(13)
Sharing of Knowledge on Strategies to boost agricultural productivity	22	6	11	3	33(9)
Promote inter/intra personal knowledge acquisition strategies to boost/sustain agricultural productivity	65	18	32	9	97(27)
Assist in negotiation for excellent pricing of farm yield	44	12	22	6	66(18)
Opening and linkages to marketing channels for agricultural products	13	4	16	5	29(9)
Encourage collaboration with experienced farmers, experts and extension personnel on measures to enhance agricultural productivity	12	3	9	3	21(6)
Total	**224**	**62**	**129**	**38**	**353(100)**

Source: Field Survey, (2023)

***Multiple Responses**

Table 2 asserts respondents received stimulus packages, training and incentives such as (Tents, Mattresses, Blankets, Health care, Knowledge on strategies to boost agricultural productivity and others) and more from governmental institutions than Non-governmental organizations. This finding is in consonant with Unaeze and Okogba 2020 who asserted that governmental organization through appropriate policy, investment and collective actions has increased the adaptation capacity of local farmers and this has been of a great benefit to Vulnerable Rural communities in the Niger Delta

Objective 2 Multiple Response on Constraints Encountered by Respondents and Institutions

Table 3 Distribution of respondents according to constraints encountered.

Variables	**Frequency**	**Percentage %**
a) Constraints Encountered by Climate Refugees (n=90)		
Nature of constraints faced		
Poor access to Resources	76	84
Poor coordination of activities	89	99
Lack of personnel	56	62
Insecurity	89	99

Source: Field Survey (2023)

***Multiple Responses**

Table 4 Distribution of Institutions according to constraints encountered.

a) Constraints encountered by Institutions (n=30)		
Item	**Frequency**	**Percentage%**
Poor Funding	27	90
Lack of synergy	26	28
Inadequate Staff and Resources	22	73
Delayed communication	19	63
Insecurity	29	63

Lack of Power	29	63
Institutional articulation and asset	29	63

Source: Field Survey, (2023)

***Multiple Responses**

The distribution of the respondents' constraints encountered by climate refugees and institutions is shown in Table 3 and Table 4 respectively

Pertinent to state that climate refugees do encounter tough problems in camps, these underlining problems make it difficult to rehabilitate them fully of the problems faced by them in the camps, and insecurity ranks among the highest. Living in the camps has not made them immune to rape, robbery, etc. Mohammed, Bukar & Mustapha. (2021) noted that reports of attacks unleashed on refugees were recorded. And this shows that Refugees are not secure in camps as they are faced with various forms of insecurity in the camps, from external aggression and internal forces thus this correlates with the research findings as seen in Table 4.1.5 which revealed that 99% of the climate refugees opined that Insecurity and poor coordination of activities were major constraints encountered by them

Going further on constraints faced by the sampled institutions, Data analysis reveals that 90% of the sampled institutions noted that poor funding has been a challenge to them whereas 63%,, 73% and 28% of the sampled institution noted Insecurity, Institutional articulation and asset, inadequate staff and Resources and lack of synergy were constraints encountered by them

Hypotheses of the Study

$H_{01:}$ There is no significant difference in the rate of intervention between Public and No governmental institutions in the study area

Table 5 Descriptive Statistics of the Intervention between Public and Non-governmental organization on Climate Refugees

	N	Range	Minimum	Maximum	Mean		Std. Deviation	Variance	Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic	Statistic	Std. Error

Governmental	7	53	12	65	32.00	7.342	19.425	377.333	-.405	1.587
Nongovernmental	7	23	9	32	18.43	2.935	7.764	60.286	.408	1.587
Valid N (listwise)	7									

Source: Field Survey, (2023)

Table 6: Paired Samples Test of the Intervention between Public and Non-governmental Organizations on Climate Refugees

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Governmental - Nongovernmental	13.571	13.587	5.136	1.005	26.138	2.643	6	.038

Source: Field Survey, (2023)

Data Analysis as seen in Tables 5 and 6, the paired sample t-test was conducted to examine the difference in means between Public and Non-Governmental Institutions. The calculated t-score was 2.643 with a p-value of 0.038, which is less than the predetermined significance level of 0.05, we reject the null hypothesis (H_0: $\mu_1 = \mu_2$) in favor of the alternative hypothesis (H_1: $\mu_1 \neq \mu_2$). Therefore, there is sufficient evidence to suggest a statistically significant difference between the means of governmental organizations and Non-governmental Organization. The test was conducted at a 95% confidence level

CONCLUSION

The study has revealed the Institutional Intervention and constraints on climate induced refugees, which would result in an expansion of the capacity of those organizations in Rivers State. The study recommended that institutions should offer options and the autonomy to decide whether and where they will be relocated in order to realize ethically acceptable responses. The study has, to a large extent, established the rate of intervention between public and non-governmental Organizations on climate refugees in the study area. Additionally, the government should develop a multi-sectoral strategy to strengthen institutions' ability to deal with the issue of climate refugees.

References

Ahmed, B. and Dewan, A. (2017), "Application of bivariate and multivariate statistical techniques in landslide susceptibility modeling in Chittagong city corporation, Bangladesh", Remote Sens, Vol. 9 No. 4, p. 304

Brisibe, W. G., & Brown, I. (2020). Building Local Resilience Capacity In Communities Vulnerable To Floods In The Orashi Region Of Rivers State, Nigeria. *International Journal Of Research-Granthaalayah*, *8*(4), 297-312.

Dissanayake, D. H. G., Mikunthan, G., & Racioppi, L. (2020). Home gardens as a resilience strategy for enhancing food security and livelihoods in post-crisis situations: A case study of Sri Lanka. In *Home Gardens for Improved Food Security and Livelihoods* (pp. 142-168). Routledge.

Mmom, P. C., & Aifesehi, P. E. (2013). Vulnerability and resilience of niger delta coastal communities to flooding. *IOSR Journal of Humanities and Social Science*, *10*(6), 27-33.

Mohammed, B. K., Bukar, M. M., & Mustapha, A. (2021). Empirical Investigation into Determinants of Non-Farm Entrepreneurial Activities among Internally Displaced Persons: Evidence from Borno State, Nigeria. *International Journal of Business Systems and Economics*.

National Emergency Management Agency (2021): Draft Report of Impacted Victims of Flooding in Rivers State

NPC (2006). National Population Commission

Nuñez, T. A., Lawler, J. J., McRae, B. H., Pierce, D. J., Krosby, M. B., Kavanagh, D. M., ... & Tewksbury, J. J. (2013). Connectivity planning to address climate change. *Conservation Biology*, *27*(2), 407-416.

Onoja, A. O. (2014) Effects Of Climate On Arable Crop Farmers'productivity, Food Security And Adaptation Strategies In Nigeria 5(10).

Raji, S., Adekayaoja, F. A., Agaku, E. A., Akujobi, J., & Hamzat, A. A. (2021). North-eastern Nigeria: assessing the response capacity of National Emergency Management Agency to the plights of internally displaced persons. *Heliyon*, *7*(6).

Unaeze, H. C., & Eloghene, O. V. (2020). Farmers Responses to Climate Change Consequences in Isoko Local Government Area of Delta State, Nigeria. *Journal of Environmental Issues and Agriculture in Developing Countries*, *12*(1).

Unaze H.C and Okoye C.U (2016): Determinants of Institutional Fcators on the cost of climate change adaptation/Mitigation programs in South eastern, Nigeria Volume 9, Issue 8 Ver. I , PP 62-67

United Nations High Commission for Refugees, 2021).

World Bank. (2020). *Global economic prospects, June 2020*. The World Bank.

IMPACT OF HUMAN ACTIVITIES ON SELECTED SACRED FORESTS IN ETCHE LGA, RIVERS STATE, NIGERIA.

Nwala, Prince C., Obute, Gordian C. and Ekeke, Chimezie
Department of Plant Science and Biotechnology, University of Port Harcourt,
P.M.B. 5323, Port Harcourt, Nigeria.

Abstract

The major aim of protecting sacred forests/groves is to uphold their sanctity through regulation of movement in and out of the sacred forest sites. Protection of the groves is very vital for biodiversity conservation in the study area. This protection which was achieved through myths, taboos and beliefs seem to have dwindled in recent times and some of the sacred groves in the study area are being depleted. Therefore, this report is focused on the impact of anthropogenic activities on selected sacred forests in Etche Local Government Area of Rivers State, Nigeria. Five (5) sacred groves in the study area were identified and visited. Custodians and elders of the villages where the groves are located were consulted and interviewed. The groves/forests visited include: Amadioha Umueze Afara (AUA), Uzi Afara (UA), Ohia Ojuo (OO), Uzo Okoromanala (UO) and Mkpa Ogbokwu (MO) forests. Sites of the sacred groves were visited and coordinates of the groves were recorded with the aid of GPS (Global Positioning System). The study showed that some parts of the sacred forests have been converted to farmland and building of residential houses leading to a threat of some indigenous economic plant species. The growth habit of plants in the study area at the time of this investigation showed that AUA forest had the highest number of trees and shrubs (32 and 28 respectively), MO had the least number of trees (21); OO had the least number of shrubs (20), UA had the least number of herbs (15) while UO had the least number of climbers (15). The study revealed that AUA was the least depleted sacred forest at the time of this investigation.

Keywords: Sacred Forest/Grove, Impact, Human Activities.

Introduction

Sacred forests, otherwise known as sacred groves have been described as areas of biodiversity conserved by the indigenes of the locality which prove to be invaluable storehouse of various flora and fauna. It can be deduced that ancestors conserve nature through preservation of sacred forests (Lucy, 2007). According to Bhagwat *et al.* (2006), over 17,000 preserved sites/groves which have saved a lot of endemic wildlife species still survive in India today. These groves also serve as habitats to wildlife species that are near extinction that may not be seen any other place around the world.

The scientific community today recognizes that ancient system of preserving sacred forests amidst man modified landscape elements is a sustainable way of natural resource harmonization with biodiversity conservation. Resources in sacred groves, especially water and non-timber products and the suitable microclimate they provided in the past years for local cultivation systems, earned a prime place for sacred forests among the traditional village communities, especially of the Indian highlands (Maihotra *et al*., 2001). In the Niger Delta region of Nigeria, where majority of the population primarily depends on forest for food, crafts, medicine, timber, etc., the importance of the forest cannot be overemphasized (UNEP, 2011).

Nevertheless, in spite of the importance of forests, there is an uncontrolled increase in forest depletion and deforestation worldwide (Pruthi and Burch, 2009). Depletion and loss of sacred forests are caused by agricultural activities, wood extraction, infrastructural development, pollution, etc. According to an estimated 10 million hectares of the vegetation might have been lost in the 20th Century, and about 80% of the original forest area is now an agriculture-forest mosaic (Norris *et al.,* 2010).

UNEP (2011) reported that prior to colonial era, forests have suffered severe anthropogenic activities thus creating serious threat to forest species including plants and animal species. Consequently, there is a considerable forest degradation leaving less than 5% of the Nigerian rainforest ecosystems as undisturbed forests (Omokhua and Asimea, 2015). Massive deforestation persists across the country and various plants and animals are under severe threat (Usman and Adefalu, 2010). Apparently, all the forest types in the Niger Delta region of Nigeria are affected by various forms of anthropogenic activities (Omokhua and Asimea, 2015). It is believed that sacred forests accommodate invisible powers and immortals which control the dynamics of life and death; and these entities are domiciled in the sacred groves. Consequently, there is a strict restriction of access by the community into these groves (Vartak and Gadgil, 1981).

However, these beliefs that contribute to the protection of the sacred groves seem to have dwindled in recent times and some of the sacred groves in the study area are being depleted. Therefore, this report is focused on the impact of anthropogenic activities on the sacred forest in Etche Local Government Area of Rivers State, Nigeria.

Etche is one of the 23 Local Government Areas of Rivers State, Nigeria. It is situated on a plain land and occupies a geographical area of approximately 3,600Km^2 predominantly used for farming and hunting. Etche LGA is situated in the North Eastern part of Rivers State (Nwogu *et al*, 2003).

Materials and Methods

Five sacred groves in Etche Local Government Area of Rivers State were identified and visited by random sampling. Custodians and elders of the villages were the groves are located were consulted and interviewed. The groves/forests include: Amadioha Umueze Afara (AUA), Uzi Afara (UA), Ohia Ojuo (OO), Uzo Okoromanala (UO) and Mkpa Ogbokwu (MO). Sites of the sacred groves were visited and coordinates of the groves were recorded with the aid of GPS (Global Positioning System).

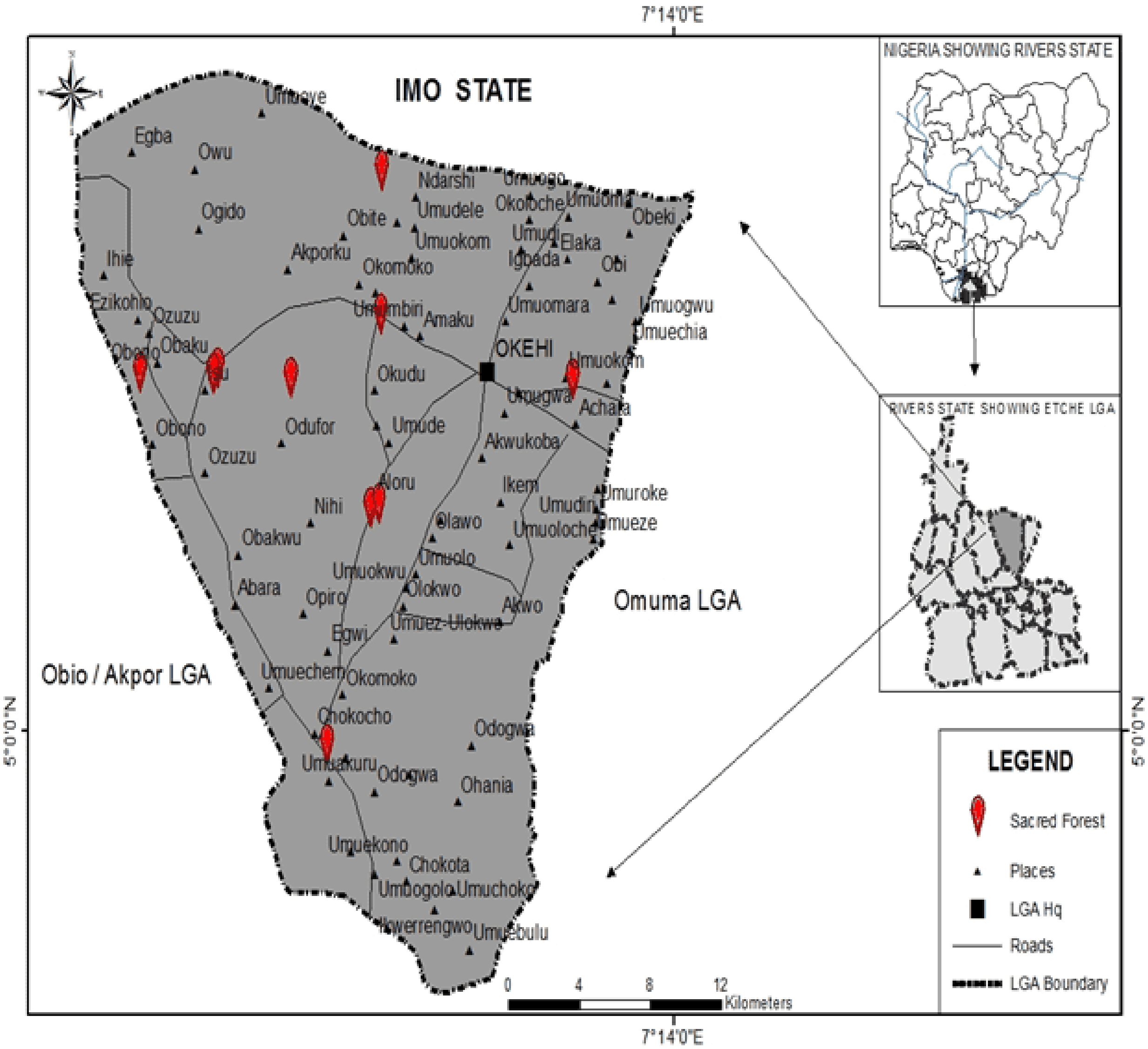


Fig. 1. Map of Study Area

Results

Table 1: Selected Sacred Forests in ELGA

S/N	Name of forest	Symbol	Name of Community	GPS Reading	Original Purpose
1	Amadioha Umueze Afara	AUA	Afara	N05° 05' 11.2" E007° 04' 47.0"	Religious rituals and festivals
2	Mkpa Ogbokwu	MO	Akwu Obuo	N05° 08' 09.11" E007° 10' 56.6"	Burial ground
3	Ohia Ojuo	OO	Umuakuru, Obite	N05° 13' 0.1" E007° 5' 08.0"	Rituals
4	Uzi Afara	UA	Afara	N05° 13' 0.1" E007° 5' 08.0"	Worship and rituals
5	Uzo Okoromanala	UO	Ozuzu	N05° 08' 17.4" E006° 59' 59.8"	Worship and rituals

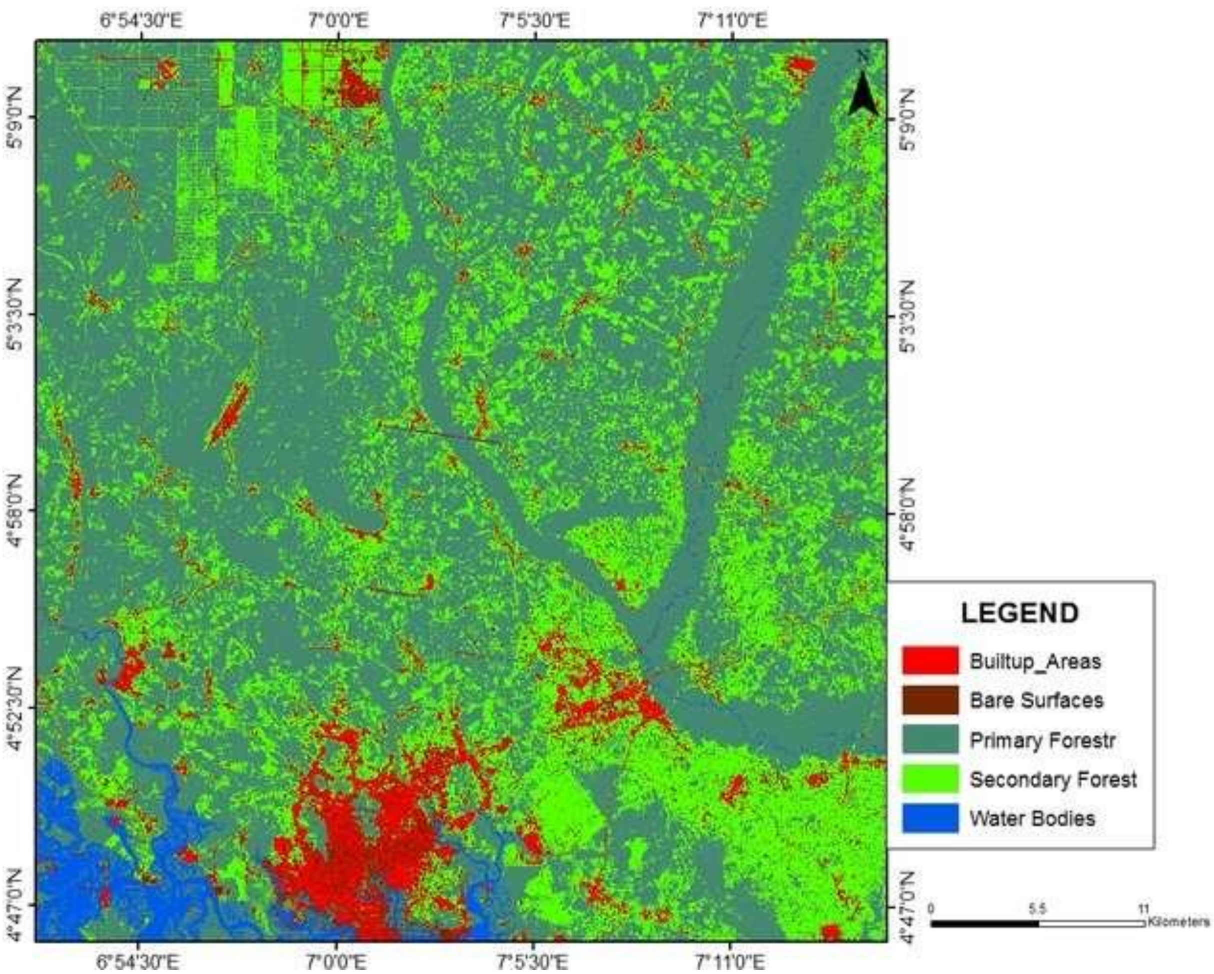


Fig.1: Impact of human activities in the study area (Satellite image, 1986)

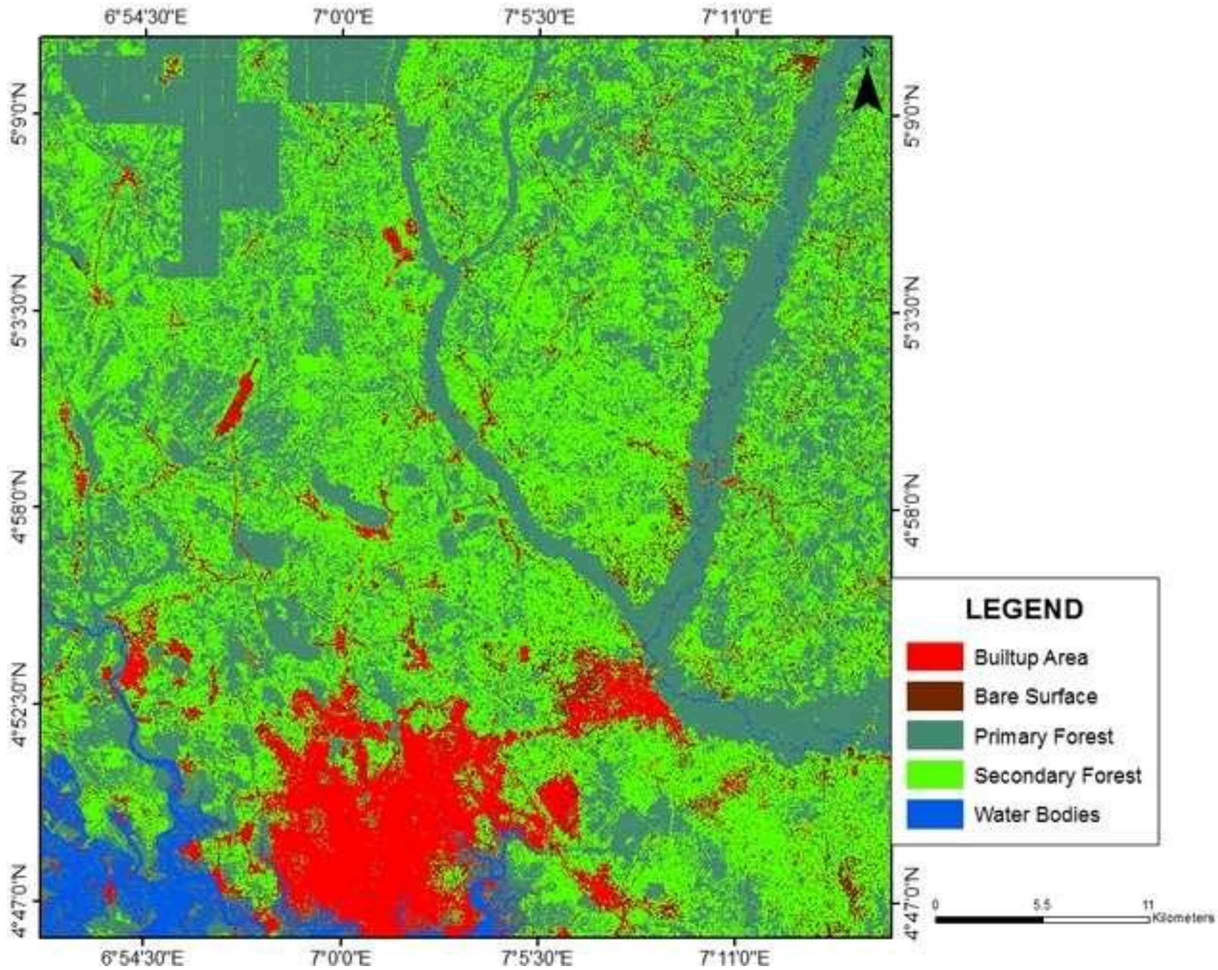


Fig. 2: Impact of human activities in the study area (Satellite image, 2001)

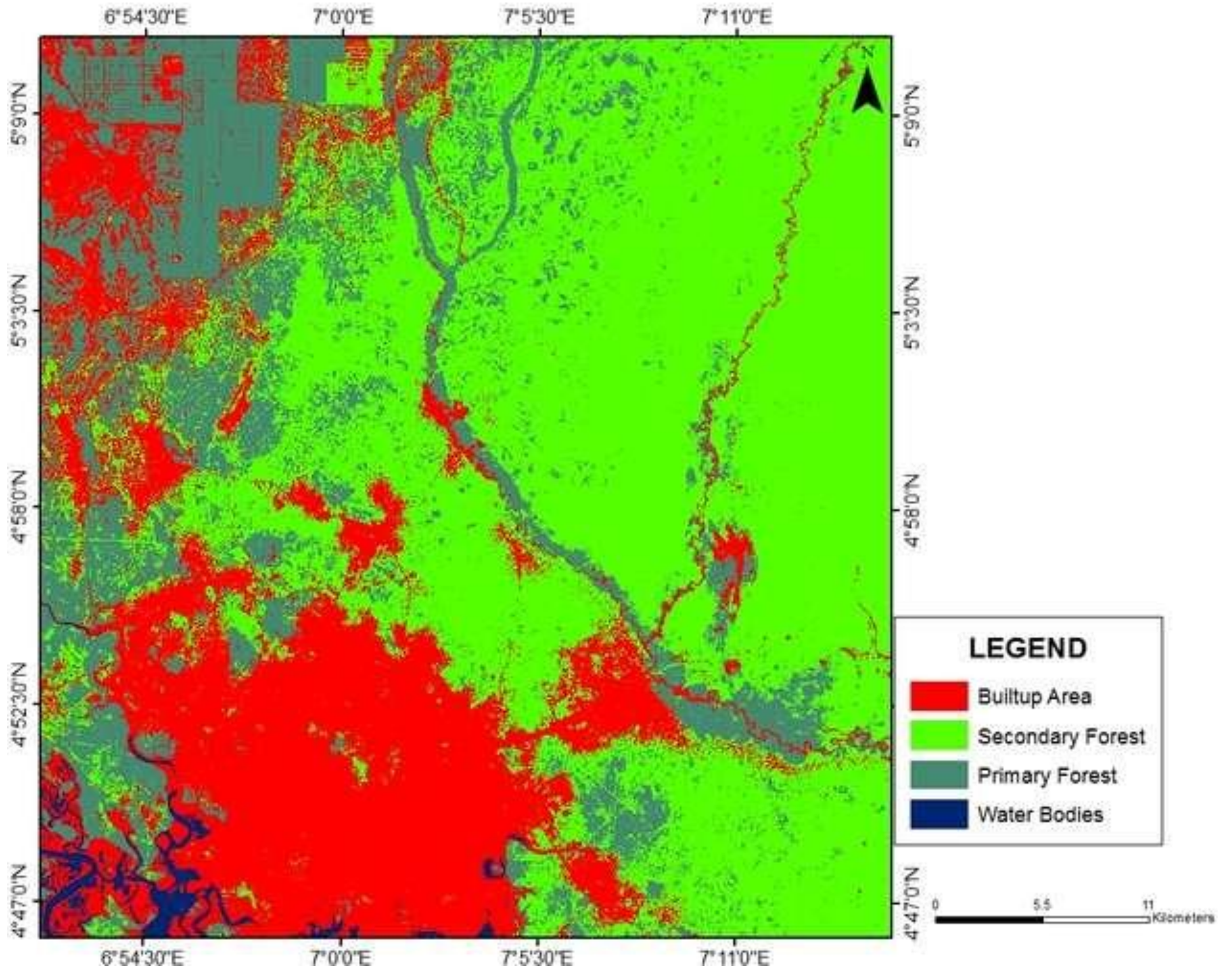


Fig. 3: Impact of human activities in the study area (Satellite image, 2018)

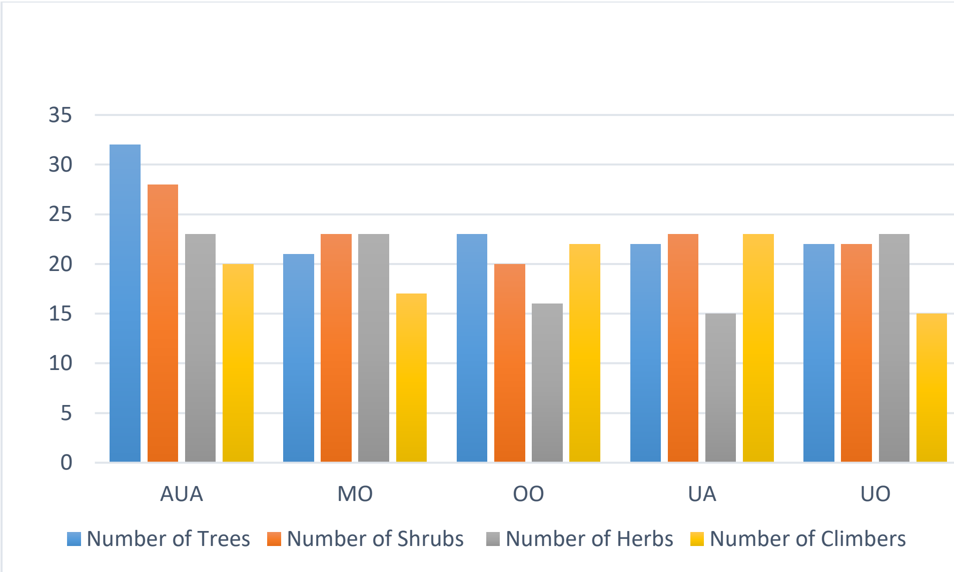


Fig. 4: Plant Growth Habit of Plants in the Study Area

Plate 1: Part of Amadioha Umueze Afara Forest used for residential building

Plate 2: Part of Uzi Afara Forest used for farmland

Plate 3: Ohia ojuo Forest burnt with fire

Plate 4: Part of Mkpa Ogbogwu Forest used for farmland

Plate 5: Part of Okoromanala Forest used for farmland

Discussion

This study revealed that most sacred forests in Etche are seriously threatened and plants species domiciled in the forest are near to threatened as some of the sacred forests have been converted to farmland, building of churches, schools, town halls, residential houses, etc (Plate 1-5).

Out of the five (5) sacred groves investigated, it was discovered that all the forests have been negatively impacted. One of the reasons for the depletion of the forests is the governance of the forest. The management of the forest is no longer effective due to the unwillingness of the indigenous people to indulge in their former practice of worship, rituals and other religious activities in the forest. Those practices have been linked to idolatry by the present generation of elders in the study area who appear to have adopted Christianity. Therefore, restriction of movement in the sacred grove became ineffective. This agrees with the report of Omokhua and Asimea (2015) who documented that sacred forests sites in Emohua Local Government Area of

Rivers State Nigeria has been deteriorating due to dwindling knowledge about respect for traditional values.

From the satellite images of 1986, it was discovered that anthropogenic activities within the study area were more focused on the southern part of the study area dominated by pockets of wet land and secondary forest which is believed to have eased human encroachment into the forest zone. Primary (virgin) forest was more noticed along the river course and the North-Eastern part of the study area while secondary forest was scattered in pockets across the study area. The nature of the forest as at 1986 enabled the categorization of delineation of forest reserve zones across the study area by the local people. This enhanced the classification of the forest belts as local shrines across the study area.

In the year 2000, there was obvious increase in the impact of anthropogenic activities across the forest area especially in the southern part of the study area as observed in 1986. This influence has resulted to a transfer of impact on the forest belt diminishing primary forest resources in favour of secondary forest resources as dominantly shown across the study area. In 2018, there was a visible increase of anthropogenic alteration spreading from the southern part to the North-Western part of the study area with a corresponding increase in the areas covered by the secondary forest area which has visibly displaced the primary forest in the study area leaving pockets of primary forest to serve as sacred forest to the indigenous people.

During study, Ohia ojuo forest was converted to a farmland through bush burning leading to destruction of various plant species in the forest. Mkpa Ogbokwu forest which was used as a burial ground for people who died mysteriously had also been converted to a farmland because of insufficient farmland for the indigenous people of Akwuobuo in Etche. Some parts of Amadioha Umueze Afara, Uzi Afara, and Okoromanala forests were used to construct residential buildings, cultivation of crops, harvesting of timbers for charcoal production. Our finding is in line with the report of Norris *et al.,* (2010) who noted that depletion and loss of sacred forests are caused by agricultural activities, wood extraction, infrastructural development etc.

The growth habit of plants in the study area at the time of this investigation showed that AUA forest had the highest number of trees and shrubs (32 and 28 respectively), MO had the least number of trees (21); OO had the least number of shrubs (20), UA had the least number of herbs (15) while UO had the least number of climbers (15). The preponderance of herbs in AUA, MO and UO forests over other growth habits in the study area is an indication that AUA, MO and UO forests were seriously impacted during the study. However, this study showed that AUA was the least depleted forest during the study. This may be due to the fear of the pre-existing myths believed by the people of the area that whoever encroaches the sacred forest would be sanctioned by the gods.

Conclusion

If the trend of uncontrolled exploitation of the sacred groves persists, the study area may be susceptible to flooding, erosion, extinction of some medicinal plants and edible wild fruits that are obtained from the forests. Similarly, other forest resources and products may be totally destroyed. Therefore, community-based laws that will prohibit people from having access to the forests should be made to protect the remaining resources of the forests.

References

Bhagwat, S.A., Kushalappa, C.G., Williams, P.H. and Brown, N.D. (2006): A Landscape Approach to Biodiversity Conservation of Sacred Groves in the Western Ghats of India. *Conservation Biology* 19, 1853-1862.

Lucy, G. (2007). *Attitudinal Values Towards Sacred Groves, Southwest Sichuan, China. Implications for Conservation*. Centre of Environmental Policy, Imperial College London, UK.

Malhotra, K.C., Gokhale, Y., Chatterjee, S. and Srivastava, S. (2001). *Cultural and Ecological Dimensions of Sacred Groves in India*, Insa, New Delhi.

Norris, K.A., Asase, B., Collen, J., Gockowksi, J., Mason, B., Phalan, A. W. (2010). Biodiversity in a forest- agriculture mosaic- The changing face of West African rainforests. *Biological Conservation*, 143, 2341-2350.

Nwogu, I., Onyeso, N., Amaele, S., Nwodim, O., Nweke, V. (2003). *History of Etche*, Springfield Publishers Limited, Owerri Imo State Nigeria.

Omokhua, G.E. and Asimea, A.O. (2015). Biodiversity Conservation and the sacred Forests of Emohua, Rivers State, Niger Delta Region, Nigeria – A Review. *International Journal of Science and Technology (STECH)*, 4(1), 37-44.

Pruthi, I. and Burch, W. (2009) Scoop-Ecological Study of Sacred Groves and Memorial Parks; Cases from USA and India. *International Journal of Environmental Science and Engineering* 1(1), 7-10.

United Nations Environment Programme (UNEP) (2011). *Environmental Assessment of Ogoni Land.* Nairobi: UNEP.

Usman, B.A. And Adefalu, L.L. (2010). Nigerian Forestry, Wildlife and Protected Areas: Status Report. *Tropical Conservancy*, 11(3-4), 54-62.

Vartak, V.D. and Gadgil, M. (1981). Studies on Sacred Groves Along the Western Ghats from Maharashtra and Goa. Role of Beliefs and Folklore. *Glimpses of Indian Ethnobotany,* 271-278.

EFFECT OF DIETARY INCLUSION OF SWEET POTATO *Ipomoea batatas* AND WATERMELON C*itrullus lanatus* PEELS ON THE GROWTH PERFORMANCE OF TILAPIA *Oreochromis mossambicus*

[1]Togi, P. D., *[1]Komi, G.W., [2]Ansa, E.J. and [1]Hart, A.I.
1 Department of Animal and Environmental Biology, Faculty of Science, University of Port Harcourt, PMB 5323, Choba, East-West Road. 2. African Regional Aquaculture Centre, Nigerian Institute of Oceanography and Marine Research NIOMR, Aluu, Port Harcourt, Rivers State.
*Corresponding author: gentle.komi@uniport.edu.ng

Abstract

This study was carried out to examine the effect of dietary inclusion of dried sweet potato peels (DSPP) *Ipomoea batatas* and dried watermelon peels (DWP) *Citrullus lanatus* on the growth performance of tilapia *Oreochromis mossambicus.* Four feed samples were formulated; T1, T2, T3 and Control such that T1 was formulated by including DSPP in normal fish feed, T2 was formulated by including DWP, T3 was formulated by including both DSPP and DWP while Control is the normal fish feed. Seventy-two (72) mixed sex tilapia fish fingerlings of average weight $10.72 \pm 0.43g$ were grouped into four with eighteen (18) fingerlings per group and further separated into three replicas of (6) fingerling per replica fed with the four feed samples. The fishes were fed twice daily with feed of 5% their body weight. The results revealed that; both DSPP and DWP are suitable as inclusion in formulating tilapia fish feed. The feed sample with DSPP (T1) performed better in weight-based growth indicators (DSPP 51.45g > DWP 45.15g). The feed sample with DWP (T2) performed better in length-based growth indicators (DWP 6.06 > DSPP 5.53) while the feed that contained both DWP and WSPP (T3) performed better than the feed sample with only DWP and WSPP (mixed DWP/WSPP 63.59 > only DWP 45.15g and only DSPP 51.45g), Therefore, it was concluded, among others, that DWP and WSPP are suitable as inclusion in formulating fish feed for tilapia fingerlings, it was recommended that fish farmers and commercial fish feed producers should consider formulating fish feed by including both DWP and WSP, thus, will improve the growth performance of the fish and also reduce the cost of fish feed.

Keywords: Non-conventional, fish feed, dried watermelon peels.

Introduction

Fish constitutes a large growing source of protein food in almost every diet consumed by humans in the world today (FAO, 2021). Fish also constitutes about 40% of the total animal protein intake by the average Nigerian hence there is great demand for fish in the country. Nigeria requires about 2.66 million metric tons of fish annually to satisfy the dietary requirement of its citizens (150 million) (FAO, 2011). Regrettably, the total aggregate domestic fish supply from all source (capture and culture fisheries) is less than 0.7 million metric tons per annum. Nigeria has to import 0.7 million metric tons of fish valued at about 8500 million annually to augment the short fall. This massive importation of frozen fish in the country has ranked Nigeria the largest importer of frozen fish in Africa (FAO, 2021).

Tilapia is a popular fish for aquaculture as it is very versatile and is tolerant of a variety of aquaculture environment, it can be farmed in brackish or salt water and also in pond or cage system.

Tilapia has become the third most important fish in aquaculture after carp and salmon; worldwide production exceeded 1.5 million metric tons (1.5 $x10^6$ tons) in 2002 and increases annually (Feessehaye and Yona, 2006). Due to their high protein content, rapid growth and palatability they are given major focus attentions. Tilapia fisheries originated in Africa and levant region in Asia. Tilapia are among the easiest and most profitable fish to farm due to their omnivorous diet, mode of reproduction (the fry does not pass through a planktonic phase), tolerance of high stocking density, and rapid growth.

Tilapia raised in inland tanks or channels are considered safe for the environment since their waste and disease is contained and not spread to the wild commercially grown tilapia are almost exclusively males. Being prolific breeders, female tilapia in the pond or tanks will result in large populations of small fish. Tilapia from aquaculture contains high ratios of omega-6 to omega-3 fatty acids Male tilapia fishes are preferred by fish farmers because they tend to grow faster than their female counterparts which spends more of their energy in the course of breeding. These activities the female tilapia get involved with is basically responsible for their stunted growth and to the advantage of the male tilapia which grows to a better table size than the females. Techniques are being researched by scientists to produce only male tilapia fish. Cultured tilapia fish can be really delicious in meals as well as a lucrative source of extra income.

Global population, and also the population of Nigeria, is increasing at an alarming rate, and this situation demands for urgent action and aggressive approach narrowed towards massive food production in order to feed the population and to resolve inadequate food supplies and the corresponding consequence of malnutrition. One of the current, viable and encouraging solutions to the problem of shortage in intake of animal protein, especially in developing countries like Nigeria, is a proper and intentional development of aquaculture (World Fish Center, 2007).

According to Sunday and Komi (2021), fish feed has been confirmed as the most expensive input factor in development and operation of aquaculture system. This high cost of feed is due to massive reliance on the limited and costly protein sources for feed formulation like fishmeal and shrimp meal (Lim *et al.,* 2011). Omoregie (2001) reported that the shortage and high-cost of fish feed severely constrained the development and operation of low-cost aquaculture systems suitable for small-scale farmers in the developing countries like Nigeria. It would therefore, be more economical to utilize plant protein in fish feed formulation than high cost animal protein materials.

According to Masudul *et* al., (2015) watermelon peel contains appreciable amount of dietary nutrition for fish feed, Watermelon contains vitamins, proteins, minerals, fat and carbohydrates (Hrubec *et al.,* 2010) while its peel, which is usually discarded as food waste, contains remarkable amount of most nutrients like phenolic antioxidants, flavonoids and lycopene (Collins *et al.,* 2007). Kays (2009) reported that sweet potato peel is devoid of most of the anti-nutrition agents as the sweet potato plant usually stores these chemicals in its tubers. hence, there is need to examine the potential of these two non-conventional ingredients (watermelon and sweet potato peels).as inclusion in fish feed formulation for Tilapia fingerlings in order to maximize fish yield and also reduce the rate of wastage of these peels.

This study is aimed at maximizing the use of watermelon (*Citrullus lanatus*) peels and sweet potatoes (*Ipomoea batatas)* peels as fish feed inclusion to enhance fish yield of Tilapia (*Oreochromis mossambicus)* fingerlings and reduce wastage of these fruits and vegetable.

This study will be important to key players in the aquaculture sector which includes commercial fish feed producing firms, small, medium and large-scale fish farmers as well as intending and potential fish farmers. The finding of this study will help them to understand the possibilities of using watermelon and sweet potatoes peel as part of the material for formulation of fish feed. The finding of this study will also be useful to scholars and researchers in plant science and animal science, especially those in aquaculture related field because it will serve as reference material which will guide them in studies that are related to this current study.

Statement of the Problem

Global population is increasing at an alarming rate, and this situation demands for urgent action and aggressive approach narrowed towards massive food production in order to feed the population and to resolve inadequate food supplies and the corresponding consequence of malnutrition. One of the current, viable and encouraging solutions to the problem of shortage in intake of animal protein, especially in developing countries like Nigeria, is a proper and intentional development of aquaculture (World Fish Center, 2007)

According to Jauncey & Ross (2010) Fish feed has been confirmed as the most expensive input factor in development and operation of aquaculture system. This high cost of feed is due to massive reliance on the limited and costly protein sources for feed formulation like fishmeal and shrimp meal (Lim *et al.,* 2011). Omoregie (2001) reported that the shortage and high-cost of fish feed severely constrained the development and operation of low-cost aquaculture systems suitable for small-scale farmers in the developing countries like Nigeria. It would therefore, be more economical to utilize plant protein in fish feed formulation than high cost animal protein materials. According to Masudul *et* al., (2015) watermelon peel contains appreciable amount of dietary nutrition for fish feed, Watermelon contains vitamins, proteins, minerals, fat and carbohydrates (Hrubec *et al.,* 2010) while its peel, which is usually discarded as food waste, contains remarkable amount of most nutrients like phenolic antioxidants, flavonoids and lycopene (Collins *et al.,* 2007). Kays (2009) reported that sweet potato peel is devoid of most of the anti-nutrition agents as the sweet potato plant usually stores these chemicals in its tubers. hence, there is need to examine the potential of these two non-conventional ingredients (watermelon and sweet potato peels) as inclusions in fish feed formulation for Tilapia fingerlings in order to maximize fish yield and also reduce the rate of wastage of these peels.

Materials and Methods

Study Area

This study was carried out at the African Regional Aquaculture Center (ARAC) Aluu, Ikwerre Local government area, Port Harcourt Rivers State Nigeria.

Experimental Design

Seventy-two (72) mixed sexed fingerling tilapia fishes of initial weight of $10.72 \pm 0.43g$ were used. The fingerlings were acclimatized in a wide small concrete pond for three days before being transferred to their respective experimental ponds. The fish samples were distributed into four different treatment groups in three replicas and each replica contained 6 fingerlings placed in a woven net arrangement and placed in a large (10m by 15m by 7m) concrete pond capable of holding 1000m^{3}volme of water. Thus, there were three fish ponds used in this experiment each fish pond contained four (4) woven net arrangement with six fishes in each woven net arrangement for each treatment group. Each fish pond was used for separate feed treatment group designated as C, T1, T2 and T3. C was the control experiment treatment group in which the fishes in woven net were fed with the normal fish feed. T1 was the experiment set up for treatment group in which the fishes in the woven net are fed with normal feed mixed with dried sweet potatoes peel, T2 was the treatment group in which the fishes in the woven net are fed with normal fish feed mixed with dried watermelon peel and T3 was treatment group in which the fishes were fed with normal fish feed mixed with both dried watermelon and sweet potatoes peels. In total there are twelve (12) woven nets arrangement distributed evenly in three (3) large concrete ponds such that each pond represents each replica of the four (4) treatment group as explained thus.

Plate 3.8: The woven net arrangement in the Fish Pond.

Duration: The experiment started on the 3rd day of March and ended 26th May 2022 making it a total of 14 weeks, however, the data which includes the weight, standard length and total length of the fishes were taken before stocking them in the ponds and after which they were measured biweekly alongside the water parameters

Feed formulation and Feeding: 35% crude protein diet was formulated using the person square method which allowed the inclusion of other materials (watermelon peels and sweet potato peels) see Table 3.1. The experimental fishes were feed at 5% of their body weight daily morning and evening between the hours of 9am- 5pm during the course of this study respectively. NOTE: The control diets were produced using only the regular fish feed materials. Four different feeds were formulated and were labeled

Feed 1: C (normal feed without inclusion)
Feed 2: T1 (Sweet potato peels inclusion)
Feed 3: T2 (Water melon peel inclusion)
Feed 4: T3 (Both inclusion)

Table 3.1 The Feed Content of the Four feed samples used in the Experiment

	10 KG fish feed diet, 35%CP				
	CONTROL	**T1**	**T2**	**T3**	
		WMP	SPP	BOTH	TOTAL KG
WATERMELON PEEL	0.00000	1.609385	0.00000	1.122813	2.732197
SWEET POTATO PEEL	0.00000	0.00000	1.667077	1.122813	2.789889
WHEATBRAN	2.803333	1.609385	1.667077	1.122813	7.202607
GARRI	0.560667	0.268231	0.277846	0.224563	1.331306
SOYABEAN	3.068	3.0065	2.944	2.9535	11.972
FISHMEAL	3.068	3.0065	2.944	2.9535	11.972
PALM OIL	0.3	0.3	0.3	0.3	1.2
BONEMEAL	0.04	0.04	0.04	0.04	0.16
SALT	0.04	0.04	0.04	0.04	0.16
PREMIX	0.04	0.04	0.04	0.04	0.16
METHIONINE	0.04	0.04	0.04	0.04	0.16
VIT.C	0.04	0.04	0.04	0.04	0.16
Total	10	10	10	10	40

Where T1 = feed with Watermelon peel inclusion, T2 = feed with sweet potato peel inclusion, T3 = feed with both watermelon and sweet potatoes peel inclusion and C = feed without the peel.

Data collection

The first data collection was on the water quality of the pond. Five major parameters were considered on water quality and they include, Dissolved oxygen Content, Temperature, pH, Ammonia content and Nitrate content.

The main data collection was focused on parameters that are required to evaluate the growth performance of the fishes in the experiment. The parameters required are:

1. Initial weight, (W_1)
2. Initial standard length, (SL_1)
3. Initial total length, (TL_1)
4. Final weight after each period, (W_2)
5. Final standard length after each period, (SL_2)
6. Final total length after each period. (TL_2)

Procedure used to measure the weight and length of the fishes; the fishes were carefully harvested from each pond into a bucket and moved to measurement table. Meter rule and weighing balance were used to measure the length and weight of the fishes respectively. After the measurement, they were returned to the ponds see plate 3. 9 and plate 3.10.

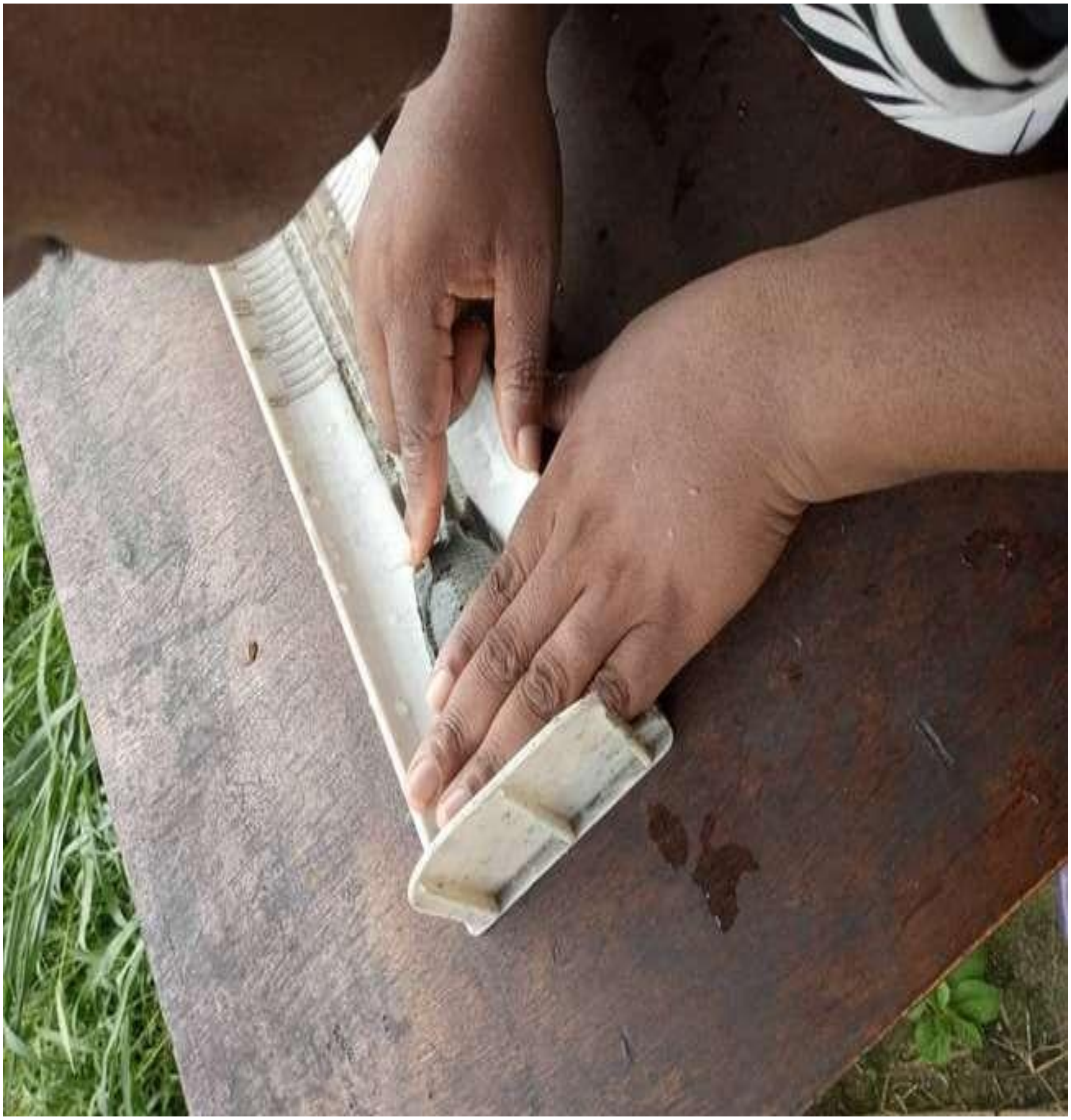


Plate 3.9 Procedure for measurement of Standard and Total Length

Plate 3.10 Procedure for measurement of Initial and final weight

The growth performance variables considered in this study are

1. **Change in Weight**; this is the increase or decrease in weight of the fish recorded within specific period and it is expressed as;
   $W_C = W_2 – W_1$
2. **Change in total length;** this is the increase or decrease in total length of the fish recorded within specific period and it is expressed as;
   $TL_C = TL_2 – TL_1$
3. **Change in standard length;** this is the increase or decrease in standard length of the fish recorded within specific period and it is expressed as;
   $SL_C = SL_2 – SL_1$
4. **Weight gain;** this is a growth performance parameter that assess the change in weight of a sampled animal with respect to the initial weighted expressed as percentage. It is expressed as WG and given as
   $$\boldsymbol{WG = \frac{\mathrm{W2 - W1}}{\mathrm{W1}} \times 100}$$
5. **Growth Rate:** this variable in expressed in three different forms based on the three changes expressed above. based on weight, the growth rate is expressed as
   $$\mathbf{GR_W} = \frac{\boldsymbol{Change\ in\ weight}}{\boldsymbol{duration\ of\ the\ experiment}} = \frac{\mathrm{W2 - W1}}{\mathbf{14}}\ \mathbf{(g/week)}$$
   Based on standard length, the growth rate is expressed as
   $$\mathbf{GR_{SL}} = \frac{\boldsymbol{Change\ in\ standard\ lenght}}{\boldsymbol{duration\ of\ the\ experiment}} = \frac{\mathrm{SL2 - SL1}}{\mathbf{14}}\ \mathbf{(cm/week)}$$
   Based on total length, the growth rate is expressed as
   $$\mathbf{GR_{SL}} = \frac{\boldsymbol{Change\ in\ total\ lenght}}{\boldsymbol{duration\ of\ the\ experiment}} = \frac{\mathrm{TL2 - TL1}}{\mathbf{14}}\ \mathbf{(cm/week)}$$

Specific Growth Rate: This is evaluated according to formula used by Solomon *et al* (2015) as

$$\mathrm{SGR} = \frac{\log \mathrm{W2} - \log \mathrm{W1}}{\boldsymbol{duration\ of\ the\ experiment}} = \frac{\log \mathrm{W2} - \log \mathrm{W1}}{14}\ \text{(per week)}$$

6. **Feed Conversion Efficiency.** This is also evaluated according to formula used by Solomon *et al* (2015) as
   $$\mathbf{FCE} = \frac{\boldsymbol{change\ in\ wight}}{\boldsymbol{feed\ intake}} \times \mathbf{100} = \frac{\mathrm{W2 - W1}}{\boldsymbol{feed\ intake}} \times \mathbf{100\ (\%)}$$
7. **Feed Conversion Ratio:** This is also evaluated according to formula used by Solomon *et al* (2015) as
   $$\mathrm{FCR} = \frac{\boldsymbol{Feed\ Intake}}{\boldsymbol{Change\ in\ weight}} = \frac{\boldsymbol{feed\ Intake}}{\mathrm{W2 - W1}}\ \text{(no unit)}$$

Data analysis and Presentation

All data used in this study were presented in form of mean±standared error. The effects of feeding treatment on different treatment group were analyzed using one-way ANOVA as was used in Marconato *et al* (2020). Duncan's New Multiple Range Test was used to separate differences among the various means using the SPSS software Version 20 and Microsoft office Excel program 2010 is also used in developing graphs and other relevant charts.

RESULTS AND DISCUSSIONS

Standard length of the Fish samples within the Feeding Period for the Four Feed Samples

From Figure 4.1, it was revealed that the initial standard length of the fish in the four culture is approximately 6.24 ± 0.32 and there is no significant difference in the initial standard length of the fish samples (P>0.05), however, the standard length increased with increase in feeding period for the four feed samples in the four different cultures without any significant difference in the length for four weeks. In the sixth week, the fish samples fed with control feed recorded the highest and significant ((P<0.05)) increase in standard length (10.30 ± 0.01) followed by fish samples feed with T3 feed sampled (9,44$\pm$ 0.48) while the fish samples fed with T1 recorded a lower increase in standard length (8.85 ± 0.63). This trend of increment in standard length continued till the end of the feeding trial in the 14 weeks after which fish samples fed with control feed recorded the highest and significant increase in standard length (13.40 ± 0.05) followed by fish samples fed with T3 (12.38 ± 0.17) while fish samples fed with T1 feed sample recorded the lowest standard length (11.85 ± 0.29),

This result means that fish sample feed with the control feed sample showed the best increase in their standard length with time within the 14 weeks of feeding trial followed by those fed with feed sample with combined sweet potatoes peel and watermelon while those fed with fed that contain only sweet potatoes peel showed the lowest increase in standard length.

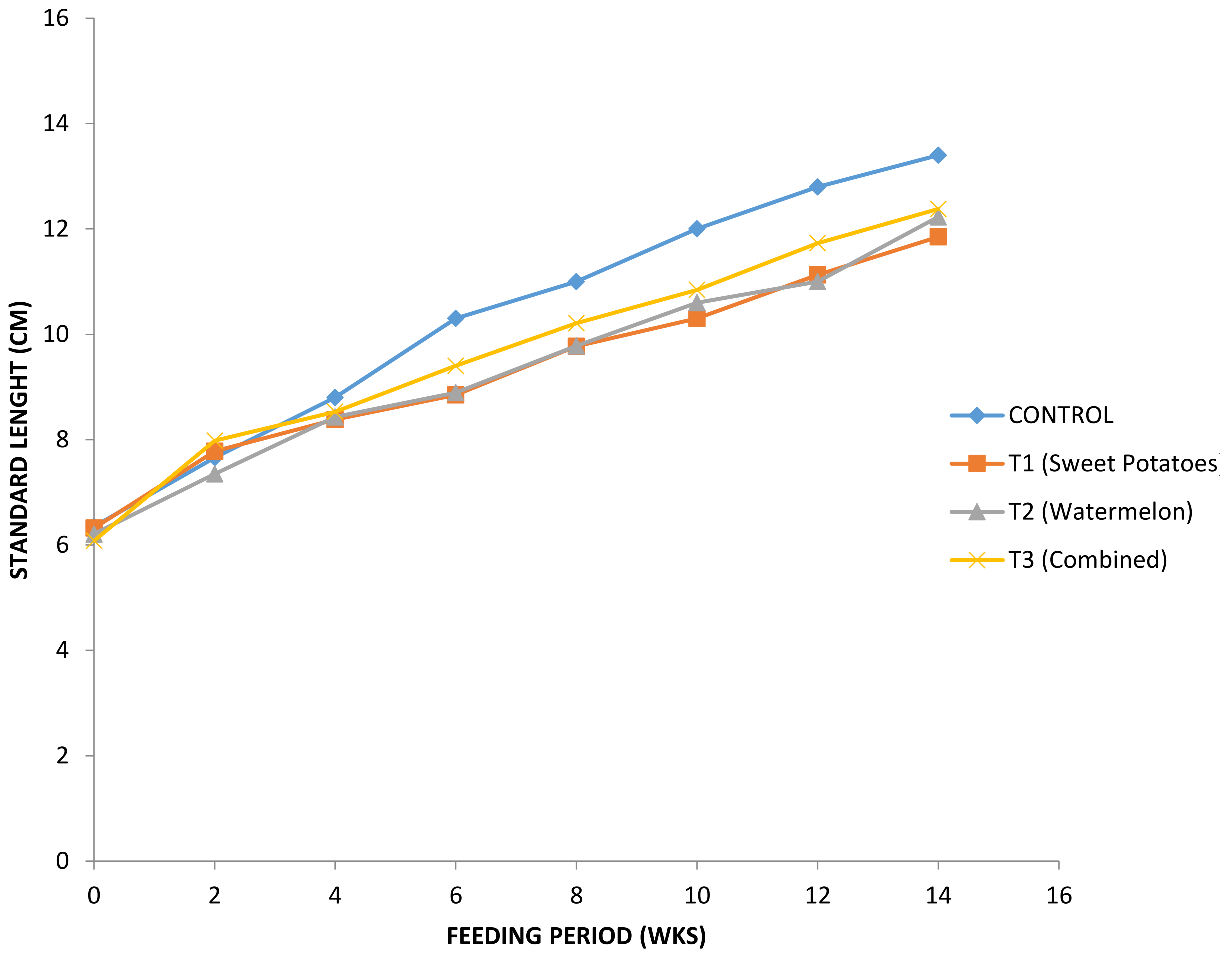


Figure 4.1 Graph of relationship between Feeding Period and Standard Length of the Fish

Change in Total length of the Fish sample with Feeding Period for the Four Feed Samples

From Figure 4.2, it was revealed that the initial total length of the fish in the four cultures is approximately 8.03$\pm$ 0.03 and there is no significant difference in the initial total length of the fishes in the four cultures (p>0.05), however, the total length increased with increase in feeding period for the four feed samples in the four different cultures without any significant difference in their total length for four weeks. In the sixth week, the fish fed with control feed recorded the highest and significant increase in total length (13.55$\pm$ 0.11) followed by fish sampled feed with T3 feed sampled (12.19$\pm$ 0.75) while the fish sampled fed with T1 recorded the lowest and insignificant increase in total length (11.38$\pm$ 0.08). This trend of growth and increment in the total length continued till the end of the feeding trial in the 14 weeks after which fish samples fed with control feed recorded the highest total length (17.10$\pm$ 0.18) followed by fish samples fed with T3 (15.92$\pm$ 0.15) while fish samples fed with T2 feed sample recorded the lowest total length (4.67$\pm$ 0.19).

This result means that fish sample feed with the control feed sample showed the best increase in their total length with time within the 14 weeks of feeding trial followed by those fed with feed sample with combined sweet potatoes peel and watermelon while those fed with fed that contain only sweet potatoes peel showed the lowest increase in total length.

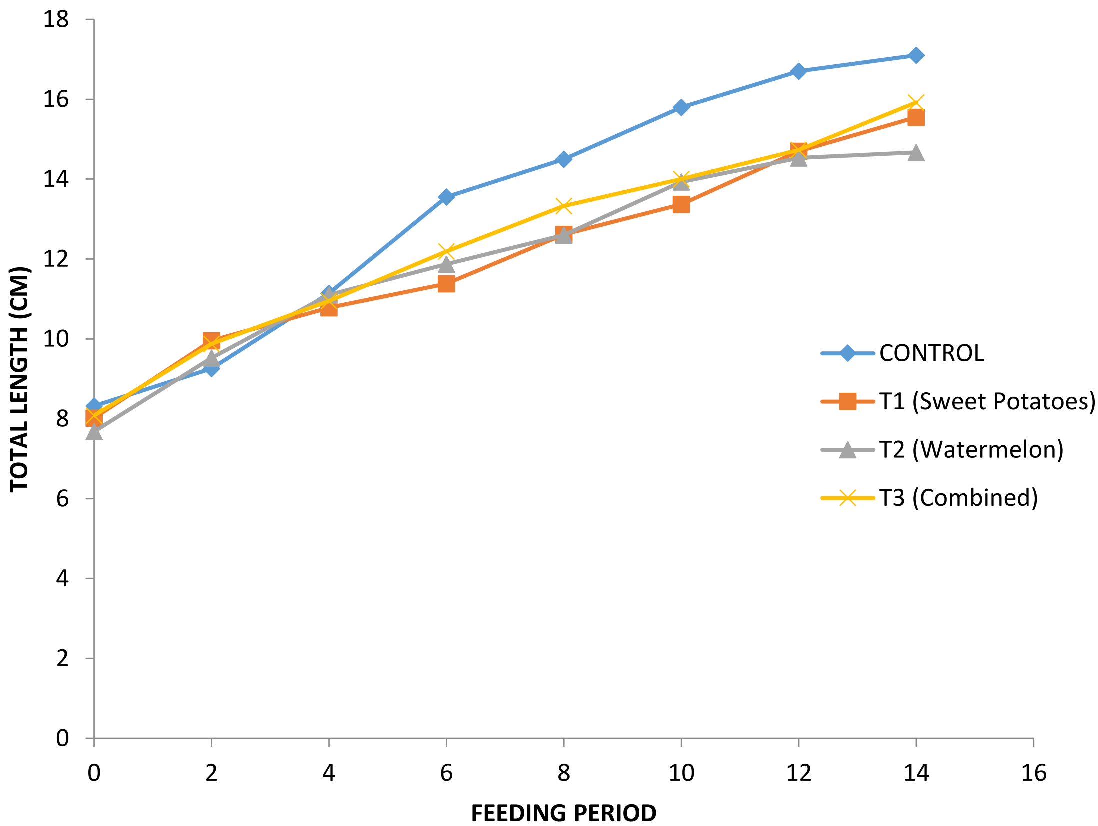


Figure 4.2 Graph of relationship between Feeding Period and Total Length of the Fish

Weight of the Fish samples with Feeding Period for the Four Feed Samples

From Figure 4.3, it was revealed that the initial weight of the fish in the four cultures is approximately 10.72$\pm$ 0.43 and there is no significant difference in the initial weight of the fish samples in the four different cultures (P>0.05) after two (2) weeks, the fish sample fed with T3 feed sample showed the highest and significant increase (P>0.05) in weight (16.50± 0.27) followed by fish samples fed with T1 feed sample (15.17± 0.47) while fish samples fed with (14.00± 0.17) showed the lowest increase in weight which not significant with increase in weight observed in fish samples feed with control feed (14.33± 0.34). After four weeks (4), the fish samples fed with control fed showed the highest and significant increase in weight (28.00± 0.54), followed by fish samples feed with T2 (26.37± 0.52) while those fed with T1 showed the lowest and significant increase in weight (24,75± 0.34). After six weeks (6), fish samples fed with control feed continua to show highest and significant increase in weight (47.50± 0.03) followed by those fed with T3 feed sample (35.11± 0.46) while those fed with T2 feed samples showed lowest and significant increase in their weights (26.79± 0.12). This trend of growth and increment in the weight observed in the after weeks continued till the end of the feeding trial in the 14 week after which fish samples fed with control feed recorded the highest and significant increase in weight (91.00± 0.11) followed by fish samples fed with T3 (74.67± 0.43) while fish samples fed with T2 feed sample recorded the lowest weight (55.67± 0.72),

This result means that fish sample feed with the control feed sample showed the best increase in their weight with time within the 14 weeks of feeding trial followed by those fed with feed sample with combined sweet potatoes peel and watermelon while those fed with fed that contain only watermelon peel showed the lowest increase in weight.

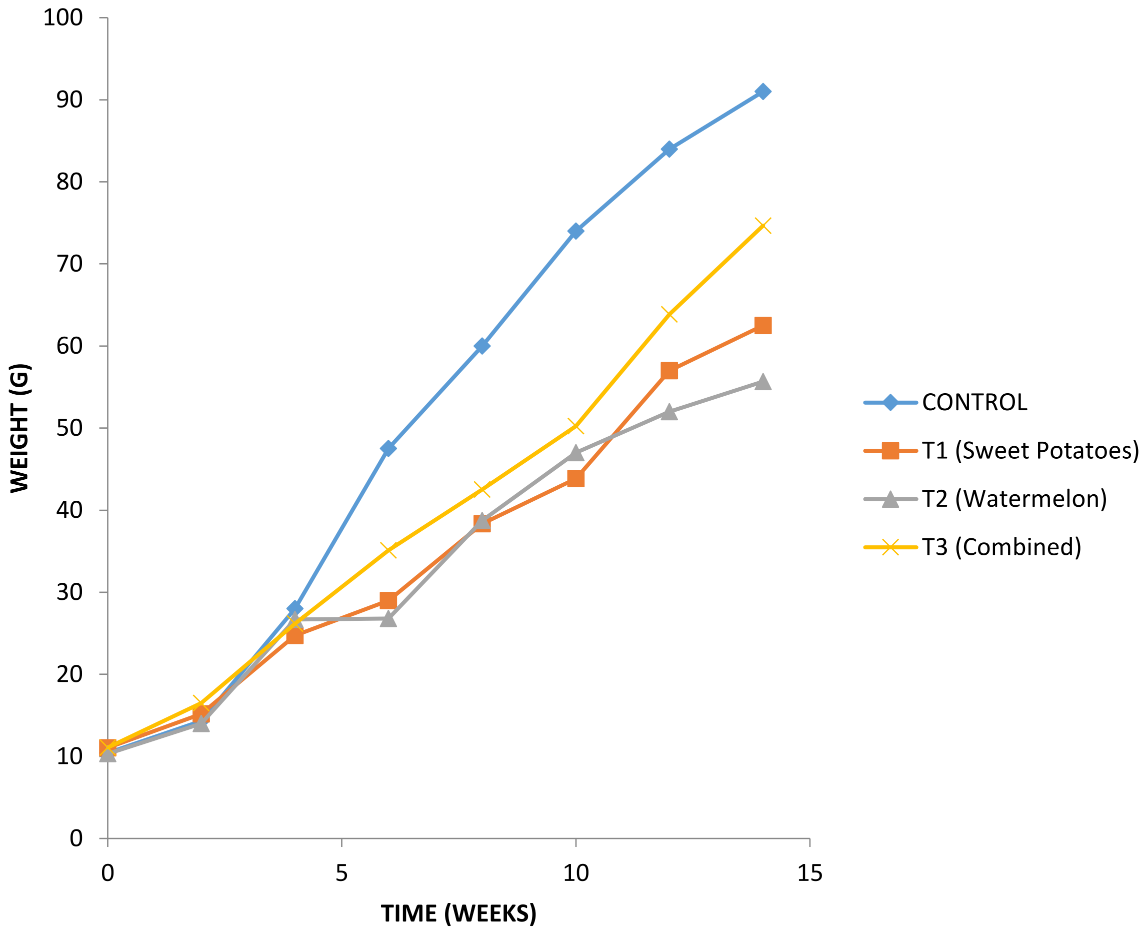


Figure 4.3 Graph of relationship between Feeding Period and Weight of the Fish samples

Weight of feed Consumed by the Fish samples within the Feeding Periods

From Figure 4.4, it was revealed that the initial weight of feed consumed by the sampled fishes in the four different cultures is approximately 5.52 ± 0.23 and there is no significant difference in the initial weight of feed consumed by the fish samples in the four different cultures ($P>0.05$) after four weeks of feeding. It was also observed that there was no significant increase in the weight of the fish samples in the four cultures after four weeks of feeding. After six weeks, feed consumed by fish samples fed with T3 is the highest (9.45 ± 0.06^{a}) but the difference was not significant with respect for feed consumed by fish samples fed with control feed (9.05 ± 0.03^{a}) while the feed consumed by those feed with T2 is the lowest (8.18 ± 0.12^{b}) but not significant with feed consumed by those feed with T1 (8.19 ± 0.02^{b}). This trend is continued as showed in Figure 4.4. However, at the end of the feeding trials, the fish samples with T3 recorded the highest total feed consumed (74.98 ± 0.07), followed by those fed with T1 (73.46 ± 0.07) while those fed with T2 recorded the lowest total feed consumed (63.63 ± 0.06)

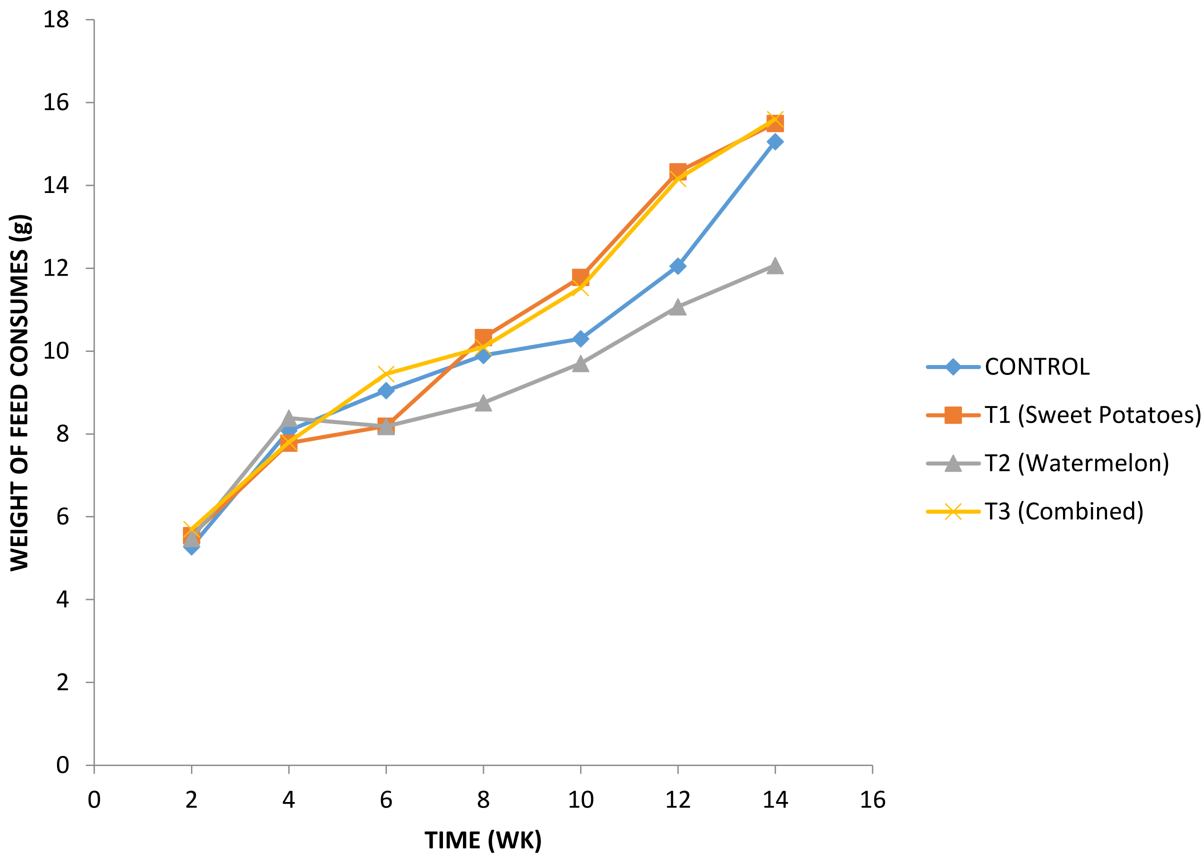


Figure 4.4 Relationship between Feeding Period and Weight of feed consumed by the Fish samples

Growth Parameters

The results of the growth parameters considered in this study are presented in this sub-section and they include change in weight, change in standard length, change in total length, Percentage weight gain, growth rate and specific growth rate.

Change in weight of the Fish samples

Change in Weight is a growth parameter that measures the increase or decrease in weight of the fish samples in the four cultures fed with the four different feed samples within 14 weeks of feeding trials in this study. In this study the results of the initial, final and change in weight for the four cultures is presented in Figure 4.5, The results revealed that fish samples fed with the control feed sample had the highest and significant ($P>0.05$) change in weight (80.57 ± 0.13^{a}) followed by fish samples fed with T3 feed sample (63.59 ± 0.49^{d}) while those fed with T2 feed sample showed the lowest and significant change in weight (45.15 ± 0.54^{c}).

These results mean that fish sample feed with the control feed sample showed the best growth performance in terms of weight increment within the 14 weeks of feeding trial followed by those fed with feed sample with combined sweet potatoes peel and watermelon while those fed with deed that contain only watermelon peel showed the lowest growth performance.

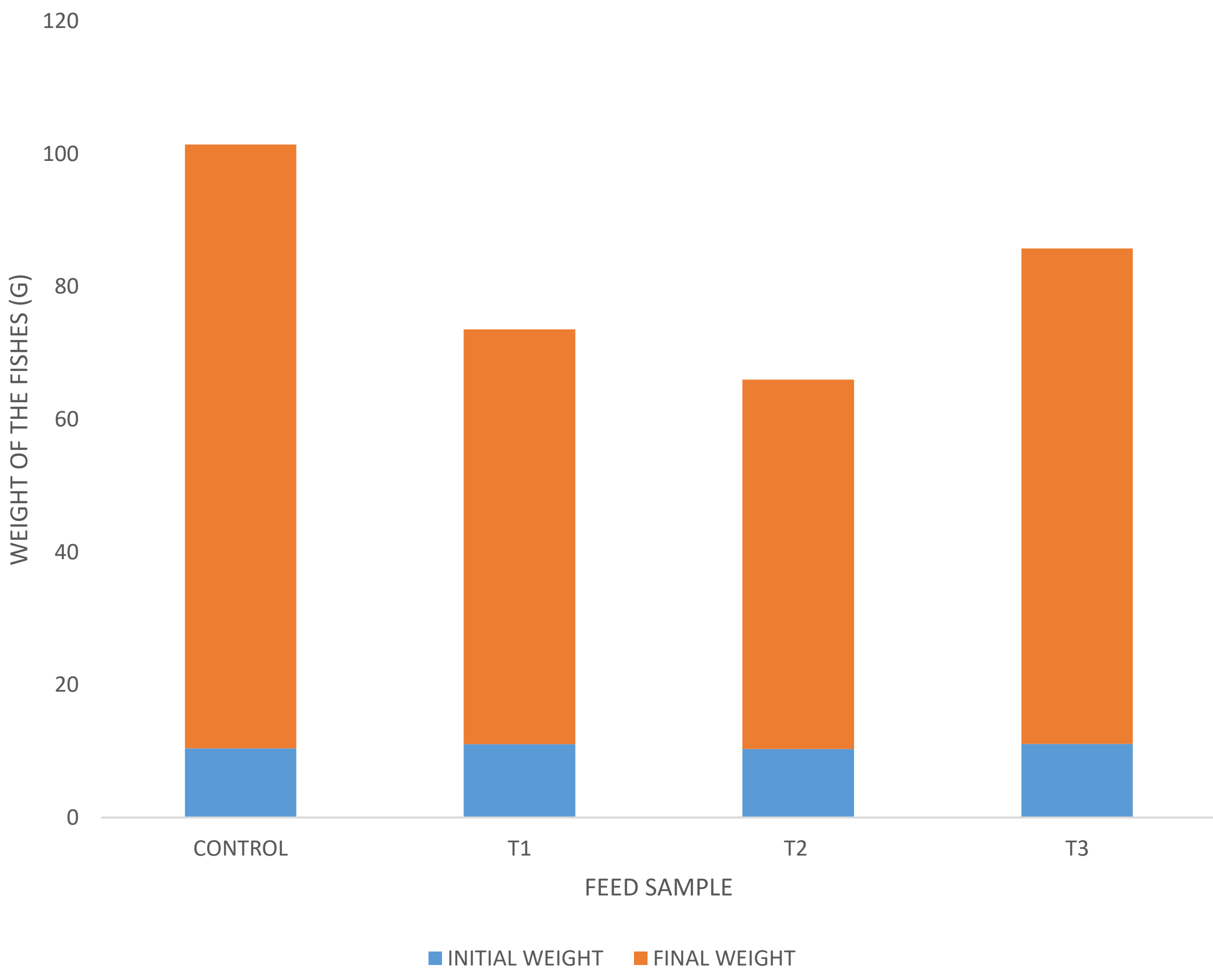


Figure 4.5 Bar chart of the weight of the Fishes for the four different feed samples

Change in standard length of the Fish samples

Change in standard length is a growth parameter that measures the increase or decrease in effective or standard part of the fish samples in the four cultures fed with the four different feed samples within 14 weeks of feeding trials in this study. In this study the results of the initial, final and change in standard length for the four cultures is presented in Figure 4.6. The results revealed that fish samples fed with the control feed sample had the highest and significant change in standard length (7.05 ± 0.19) followed by fish samples fed with T2 feed sample (6.02 ± 0.15^b) while those fed with T1 feed sample showed the lowest and significant change in standard length (5.53 ± 0.26^b).

These results mean that fish sample feed with the control feed sample showed the best growth performance in terms of increment in length within the 14 weeks of feeding trial followed by those fed with feed sample with watermelon while those fed with feed that contain only sweet potatoes showed the lowest growth performance.

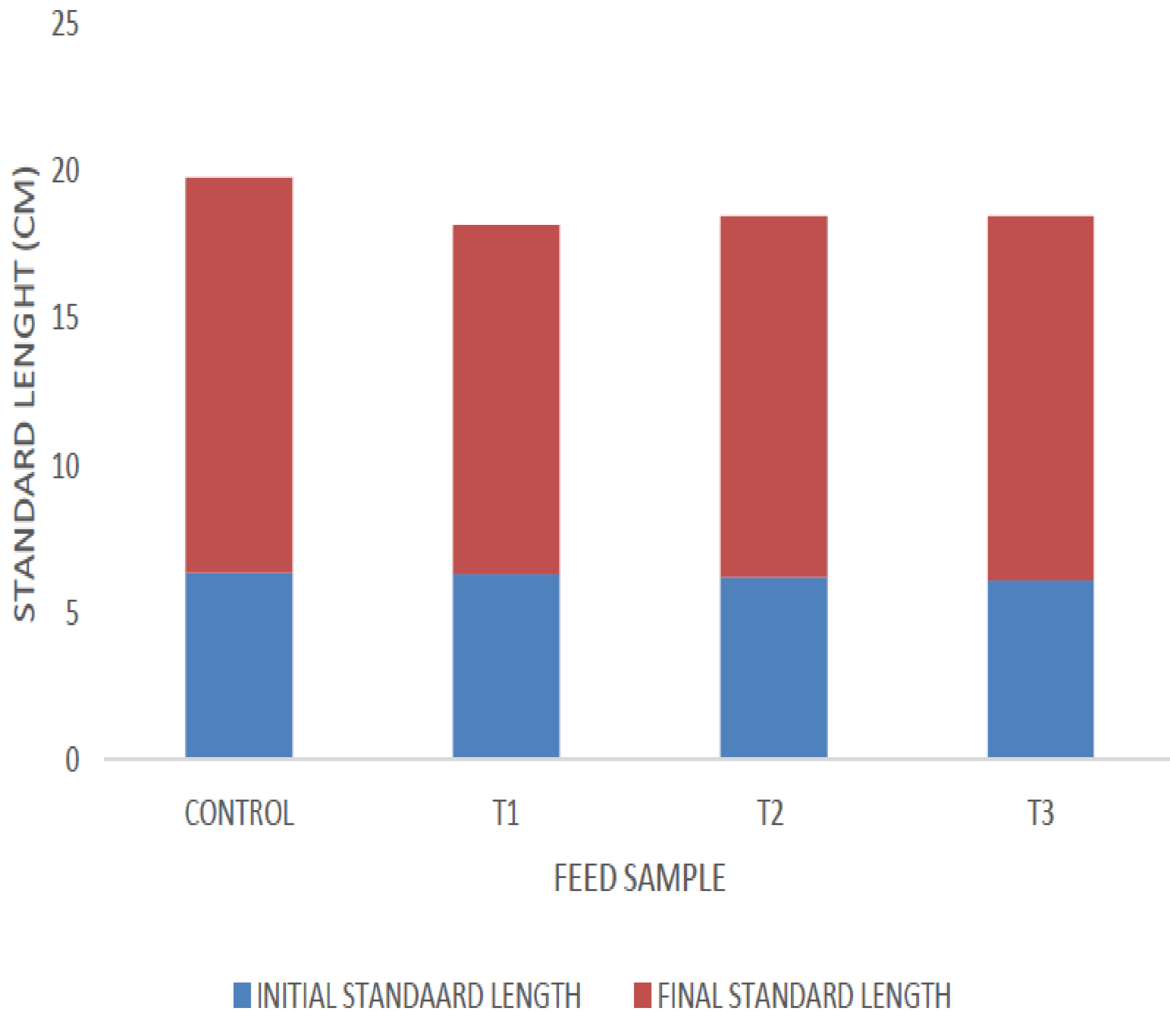


Figure 4.5 Bar chart of the Standard length for the four different feed samples

Change in Total Length of the Fish samples

Change in total length is a growth parameter that measures the increase or decrease in entire length of the fish samples in the four cultures fed with the four different feed samples within 14 weeks of feeding trials in this study. In this study the results of the initial, final and change in total length for the four cultures is presented in Figure 4.7, The results revealed that fish samples fed with the control feed sample had the highest and significant change in total length (8.78$\pm$ 0.25[a]) followed by fish samples fed with T3 feed sample (7.87$\pm$ 0.31[b]) while those fed with T2 feed sample showed the lowest and significant change in weight (6.99$\pm$ 0.17[c]).

These results mean that fish samples feed with the control feed sample showed the best growth performance in terms of total length increment within the 14 weeks of feeding trial followed by those fed with feed sample with combined sweet potatoes peel and watermelon while those fed with feed that contain only watermelon peel showed the lowest growth performance.

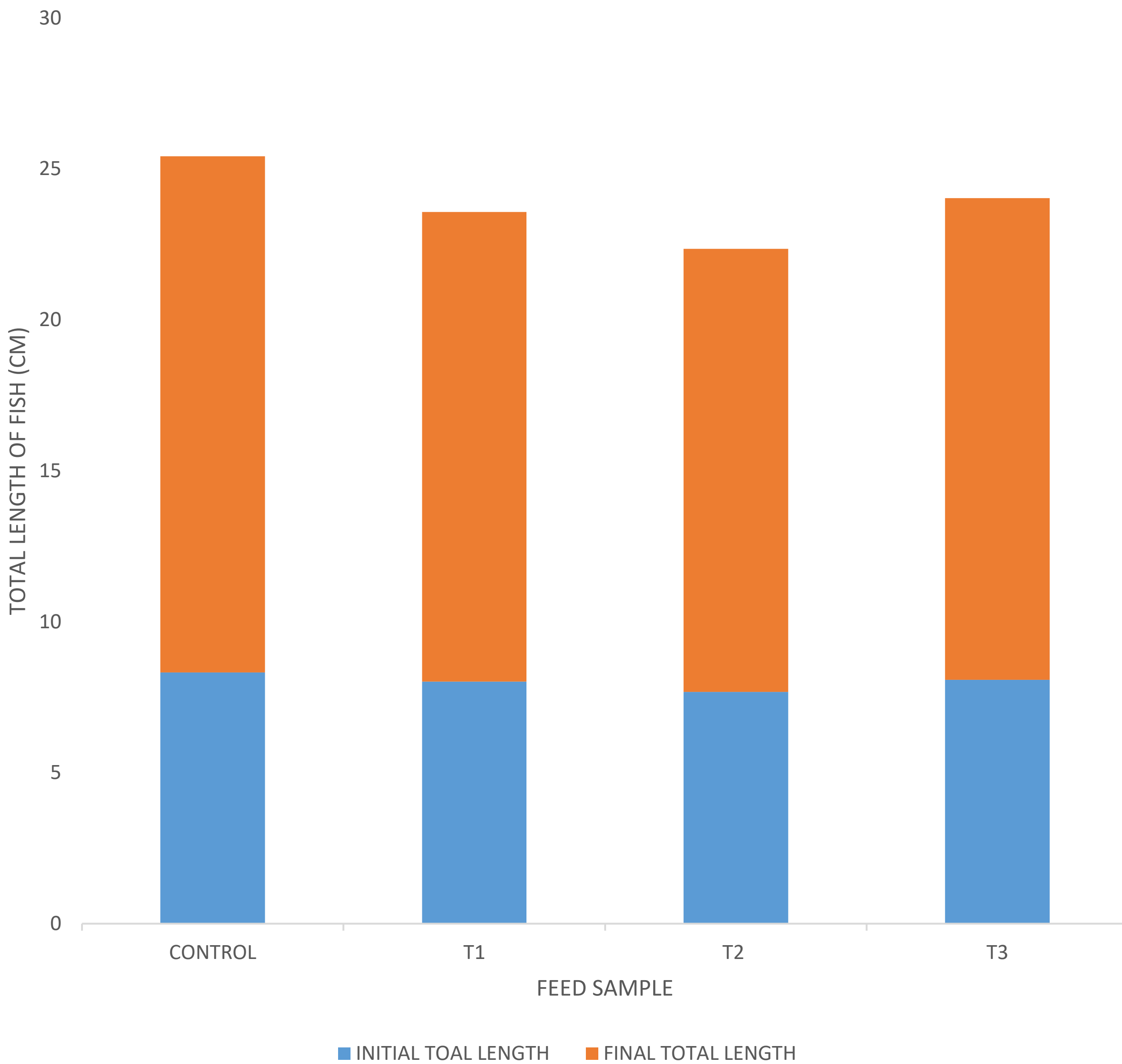


Figure 4.6 Bar chart of the Total Length for the four different feed samples

Percentage Weight Gain of the Fish samples

Parentage Weight gain is a growth performance parameter that assess the change in weight of the fish samples with respect to the initial weighted of the same samples expressed as percentage. The results in Figure 4.7 revealed that fish samples fed with the control feed sample had the highest and significant (P>0.05) change in weight (772.48 [a]) followed by fish samples fed with T3 feed sample (573.92[c]) while those fed with T2 feed sample showed the lowest and significant change in weight (437.50 [b]).

These results showed that fish sample feed with the control feed sample showed the best growth performance in terms of weight gain within the 14 weeks of feeding trial followed by those fed with feed sample with combined sweet potatoes peel and watermelon while those fed with feed that contain only watermelon peel showed the lowest in this growth parameter.

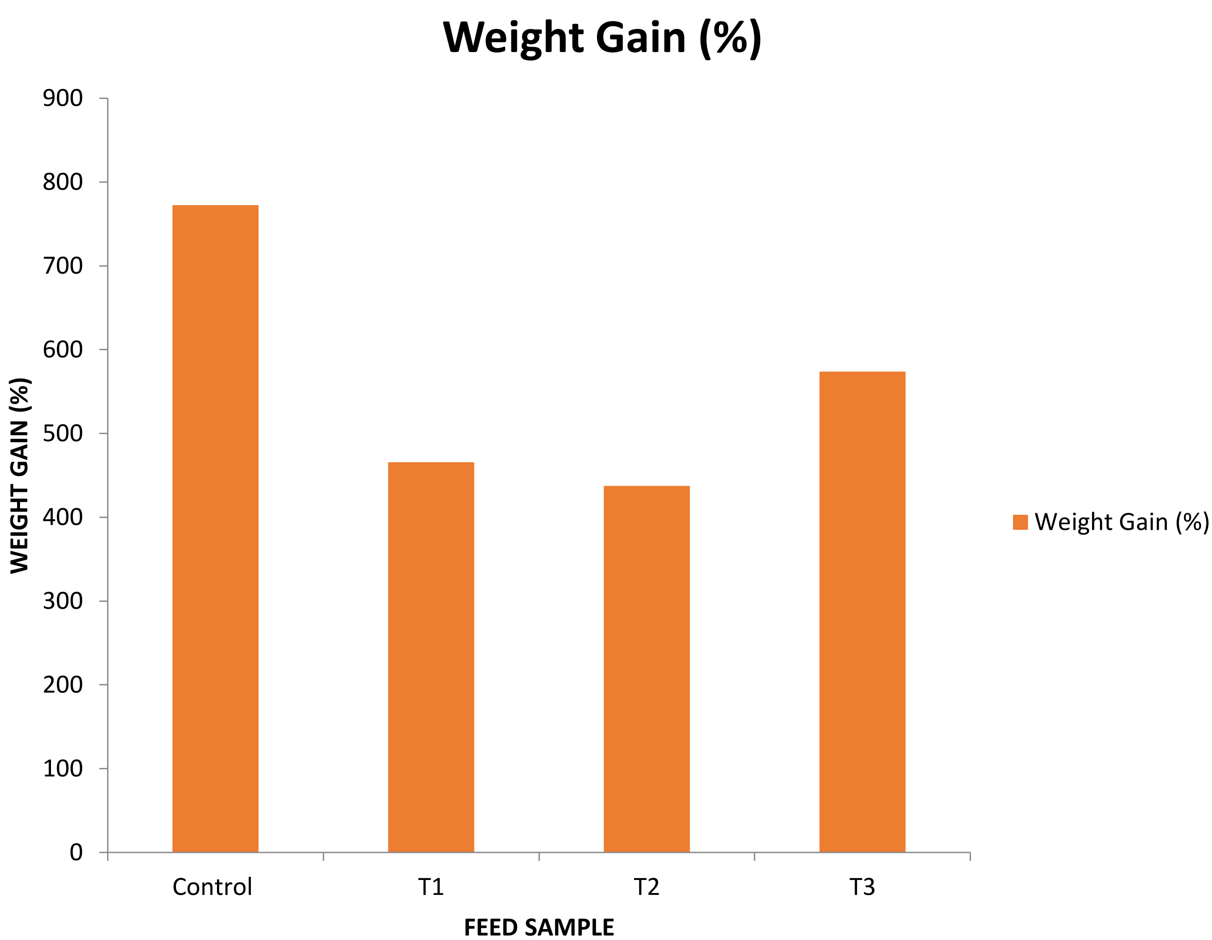


Figure 4.7 Bar chart of the Weight Gain by the fish sampled feed with the four different feed samples

Growth Rate of the Fish samples

Growth Rate is another crucial growth indicator that expressed that rate of increment per unit time. In this study, the growth rate is expressed in three different forms based on the three changes expressed above.

Growth rate based on weight; In Figure 4.8, The results revealed that fish samples fed with the control feed sample had the highest and significant growth rate based on weight (5.76^a) followed by fish samples fed with T3 feed sample (4.54^c) while those fed with T2 feed sample showed the lowest and significant change in weight (3.23^b).

These results mean that fish sample feed with the control feed sample showed the best growth rate with respect to their weight within the 14 weeks of feeding trial followed by those fed with feed sample with combined sweet potatoes peel and watermelon while those fed with feed that contain only watermelon peel showed the lowest in this growth rate based on weight.

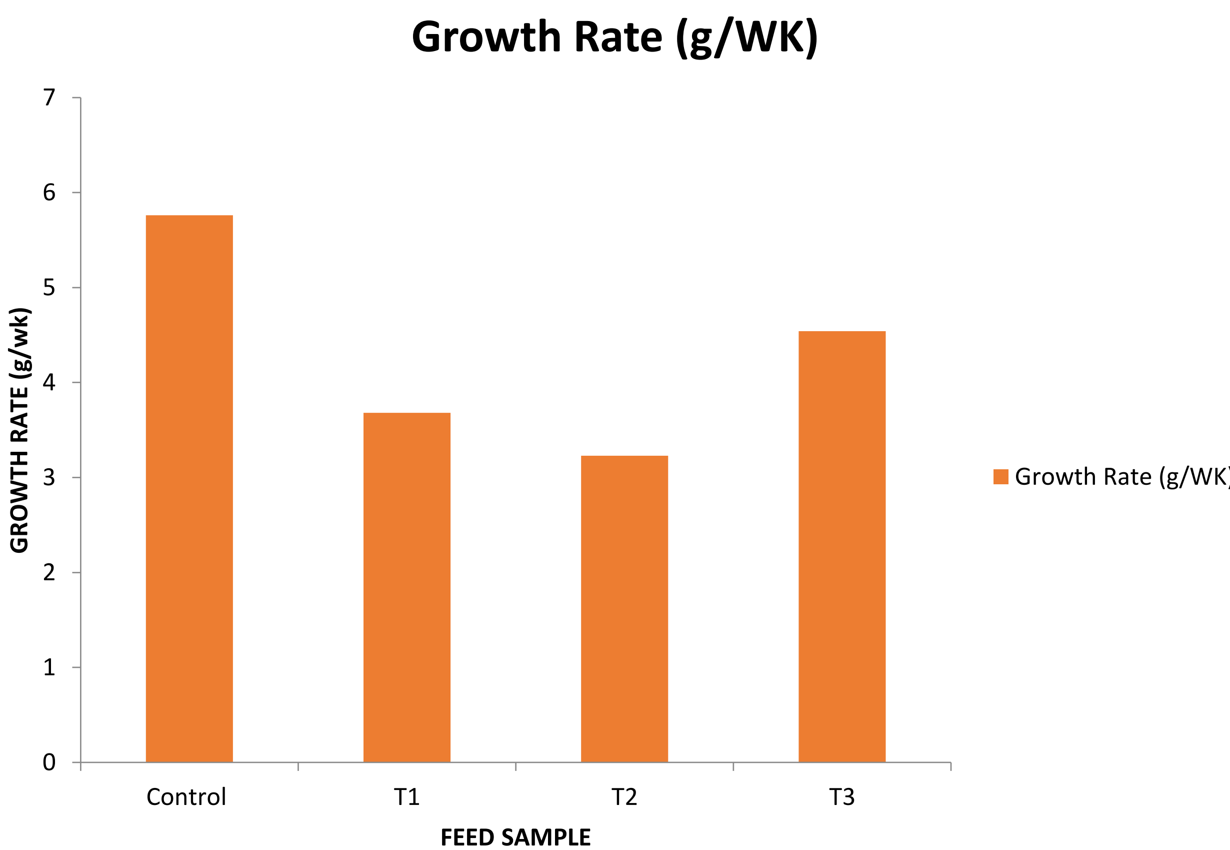


Figure 4.8 Bar chart of the Growth rate based on Weight of the fish sample

Growth rate based on standard length; In Figure 4.9 show the results of growth rate based on standard length The results revealed that fish samples fed with the control feed sample had the highest and significant growth rate based on standard length (0.50^{a}) followed by fish samples fed with T2 feed sample (0.43^{b}) while those fed with T1 feed sample showed the lowest and significant change in standard length (0.40^{b}).

These results mean that fish sample feed with the control feed sample showed the best growth rate performance in terms of increment in standard length within the 14 weeks of feeding trial followed by those fed with feed sample with watermelon while those fed with feed that contain only sweet potatoes showed the lowest growth rate based on standard length.

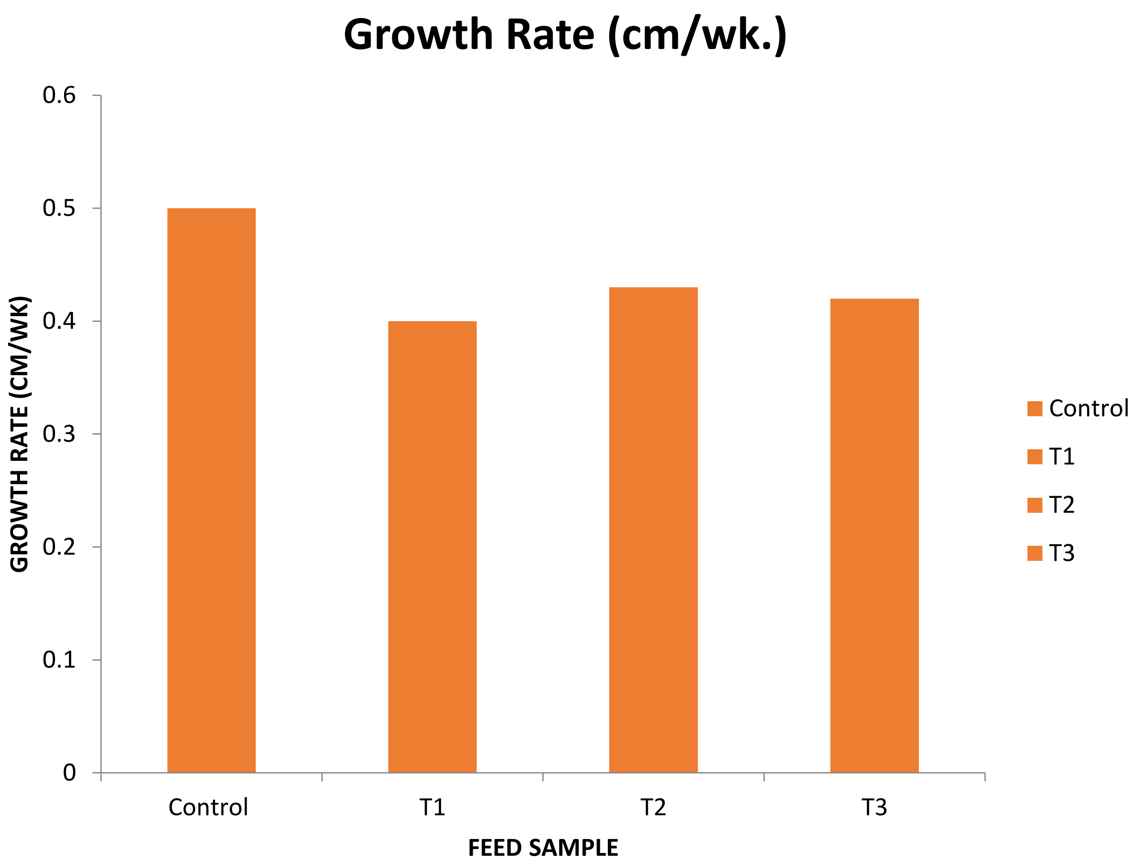


Figure 4.9 Bar chart of the Growth rate based on standard length of the fish sample

Growth rate based on Total Length; Figure 4.10 show the results of growth rate based on total length, The results revealed that fish samples fed with the control feed sample had the highest and significant (P>0.05) growth rate based on total length (0.62^{a}) followed by fish samples fed with T3 feed sample (0.56^{b}) while those fed with T2 feed sample showed the lowest and significant change in weight (0.50^{b}).

These results mean that fish sample feed with the control feed sample showed the best growth rate performance in terms of total length within the 14 weeks of feeding trial followed by those fed with feed sample with combined sweet potatoes peel and watermelon while those fed with feed that contain only watermelon peel showed the lowest in this growth parameter.

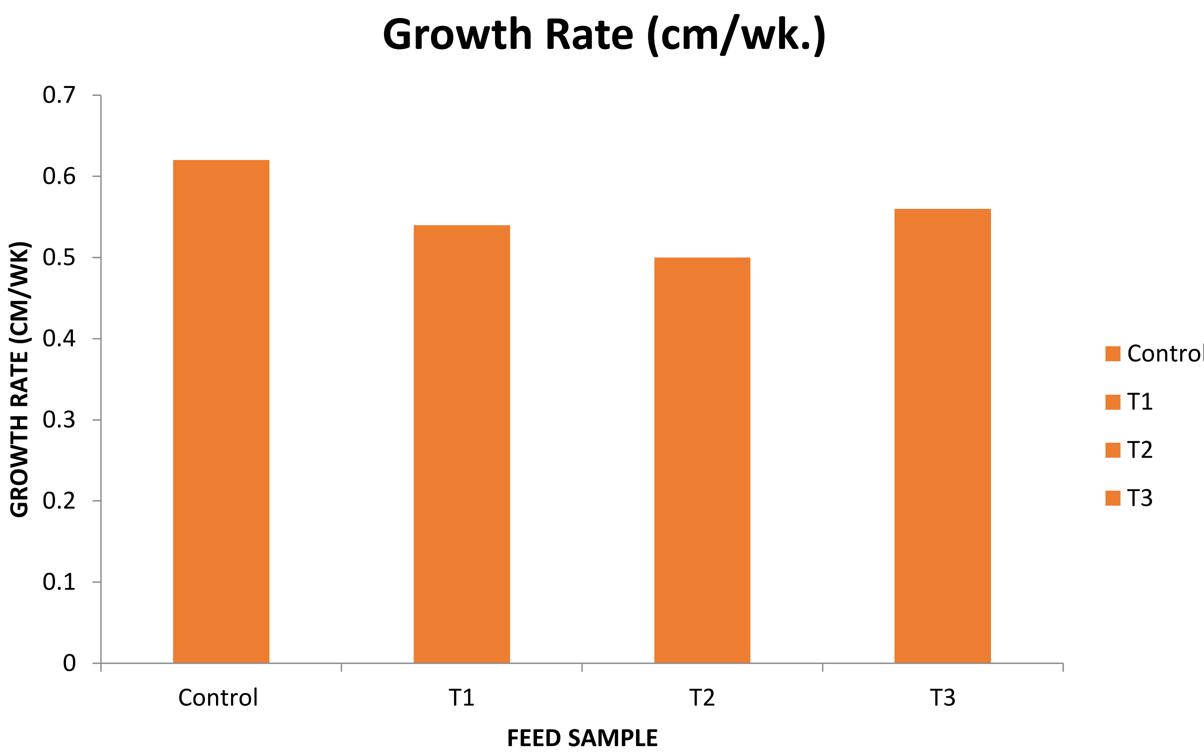


Figure 4.10 Bar chart of the Growth rate based on total length of the fish sample

Specific Growth Rate of the Fish samples

Specific Growth Rate; Figure 4.11 show the results of specific growth rate of the fish samples feed with the four different feed samples., The results revealed that fish samples fed with the control feed sample had the highest and significant specific growth rate (0.067^{a}) followed by fish samples fed with T3 feed sample (0.060^{c}) while those fed with T2 feed sample showed the lowest and significant change in weight (0.052^{b}).

These results mean that fish sample feed with the control feed sample showed the best specific growth rate within the 14 weeks of feeding trial followed by those fed with feed sample with combined sweet potatoes peel and watermelon while those fed with feed that contain only watermelon peel showed the lowest in this growth indicator.

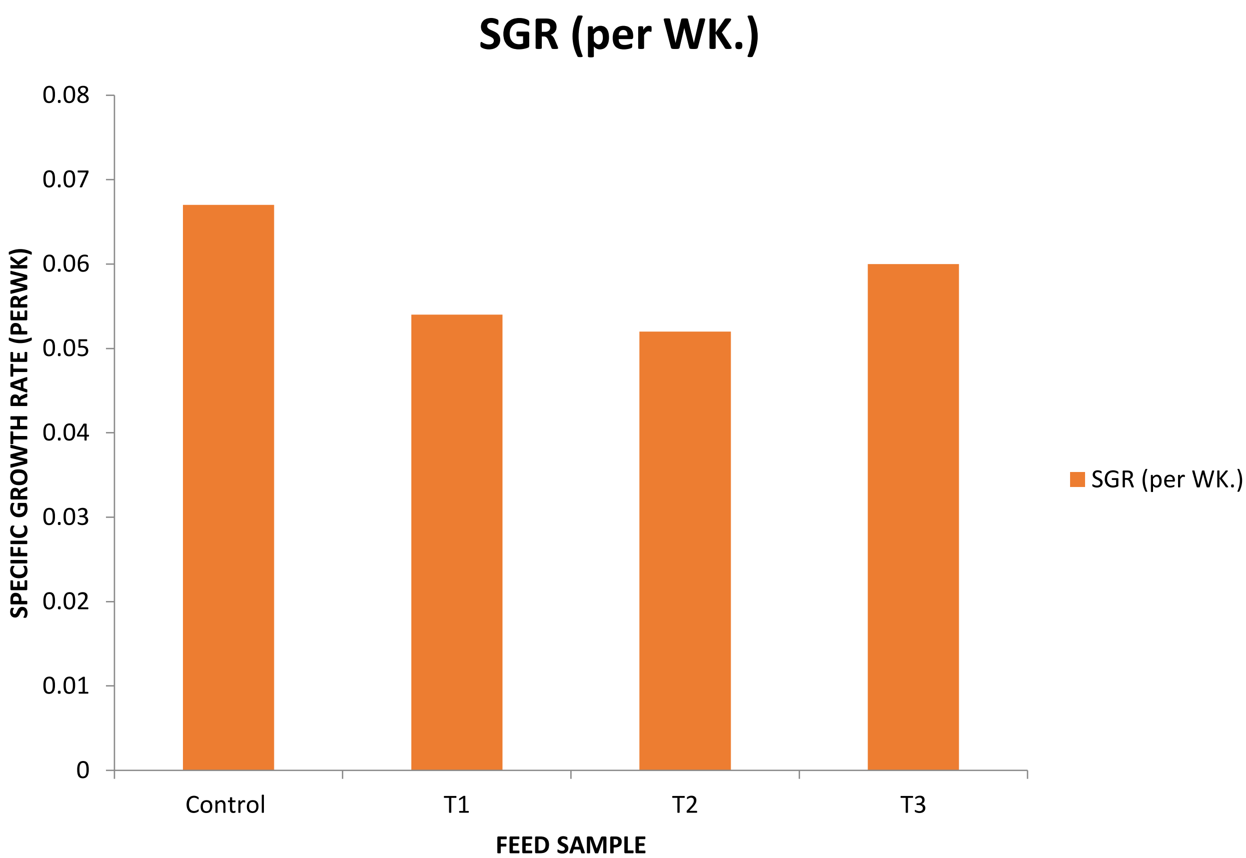


Figure 4.11 Bar chart of the Specific Growth rate of the Fish sample Fed with the four Feed samples

Feed conversion ratio

Feed Conversion Ratio is a feed utilization indicator that measures the amount of feed required to achieve a unit gain in weight of the fish. The lower the feed conversion ratio the better the performance of the fish sample: thus, the feed sample with low FCR is considered a better feed because it takes only small portion of the feed to achieve a unit gain in weight**.**

Figure 4.12 show the results of feed conversion ratio of the fish samples feed with the four different feed samples., The results revealed that fish samples fed with the control feed sample had the best and significant feed conversion ratio (0.87^{a}) followed by fish samples fed with T3 feed sample (1.18^{c}) while those fed with T1 feed sample showed the lowest and significant feed conversion ratio (1.43^{b}).

These results mean that fish sample feed with the control feed sample showed the best feed utilization based on feed conversion ratio within the 14 weeks of feeding trial followed by those fed with feed sample with combined sweet potatoes peel and watermelon while those fed with feed that contain only sweet potatoes showed the lowest feed utilization based on feed conversion ratio.

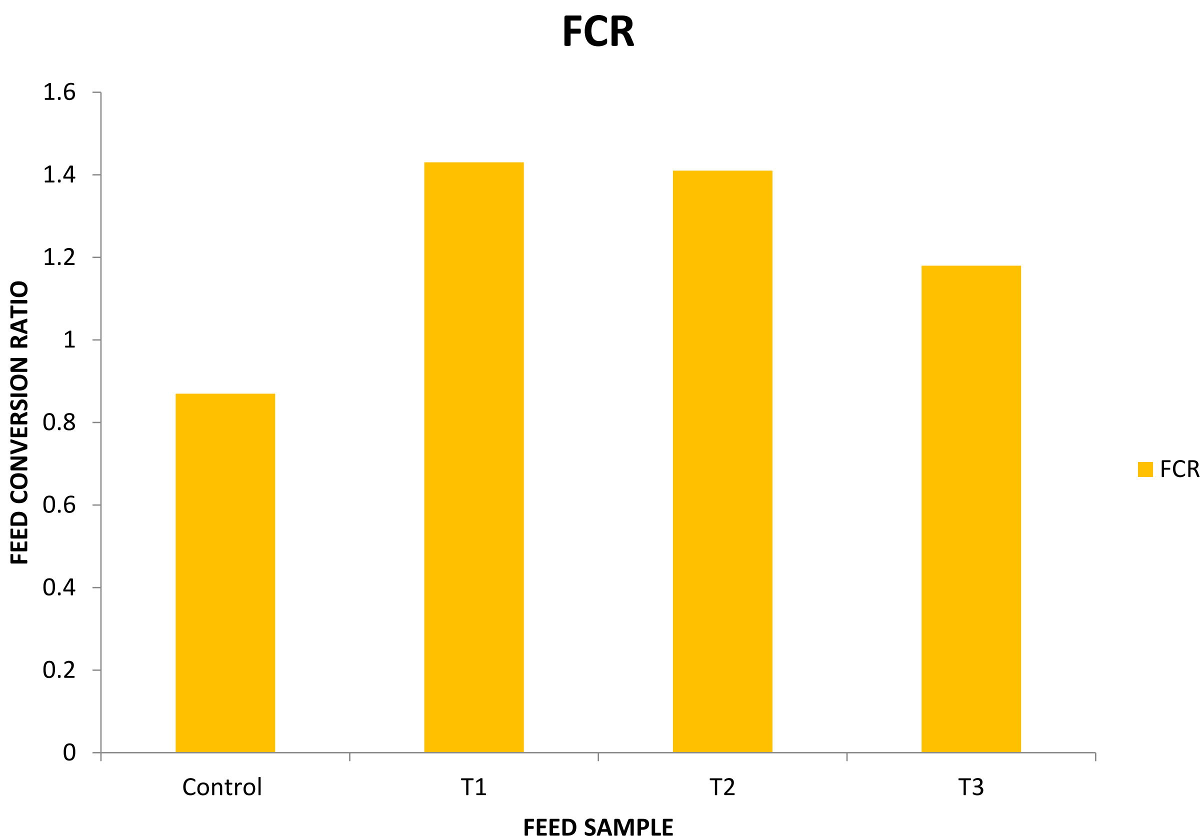


Figure 4.12 Bar chart of the Feed Conversion Ratio of the Fish sample Fed with the four Feed samples

Discussion of Findings

The results of the formulation and experimental trial of the three feed samples formulated by inclusion of dried sweet potatoes peels, watermelon peels and combination of dried sweet potatoes peels and watermelon peels denoted as T1, T2 and T3 respectively revealed that the feed samples are suitable for fish feeding because the growth indicators of the fish samples fed with the three feed samples such as the standard length, total length and weight increased appreciably with increase in experimental feeding period which lasted for 14 weeks. This is a good indication that the three feed samples contain the necessary feed nutrient required for the growth and maturity.

The outcome of this feeding trial is in line with the results presented by Faramarzi *et al* (2012) who carried out experiment study to ascertain the performance of the mixed sex Cat-fish fingerlings fed with different levels of dried sweet potato peels and the results of their study revealed that dried sweet potato peels is suitable as an inclusion in fish feeds without severe nutritional impact of the fish and basically to reduce feed formulation cost. The outcome also concurred with research carried out by Solomon *et al.,* (2015) who conducted empirical study aimed at investigating the viability and suitability of using dry sweet potato peel as energy source and to replace increasingly conventional yet expensive yellow maize feed stuff in feed for African catfish fingerlings and the outcome of their study reveals that sweet potatoes peel can completely be used to replace maize at 30% inclusion level.

This outcome of this current study on growth performance of dry watermelon peel concurred with the work carried out by Oladipupo and Salami (2020) who carried out empirical study to examine nutritional viability of feeding catfish with watermelon peel as an inclusion in the feed and their results revealed inclusion of watermelon peel in feed of catfish was ideal for improving their growth parameters., and also the work Iheanacho *et al.,* (2018) who carried out a study to ascertain the impact of inclusion of different amount of peel of water melon on growth juveniles of *Oroechromis niloticus* and their results revealed that dried peel of water melon is suitable as inclusion in the fish feed

The outcome of current study on the combination of both dried watermelon and sweet potatoes peel also align with empirical study by Omokore and Oluwafemi (2020) who conducted feed trial to ascertain the possible impacts of using dried watermelon peel and sweet-orange peel mixture as feed for rabbits considering their performance in terms of growth and their results revealed that the feed formulated with dry watermelon and sweet potatoes peel contained numerous bioactive chemicals and nutrients that can support growth of animals and it could be used as feed for rabbits with no negative impact in their overall performance.

The results of this current study on the impact of the feed containing only dried sweet potatoes peels on the growth performance of tilapia fingerling revealed that the feed sample formulated by including only dry sweet potatoes peels was better in improving the growth performance indictors based on weight of the fish samples because it contained good amount of caloric but the feed sample has limitation in improving the growth indicators based on length because it contains certain level of anti-nutrient that hinders increment in growth indicators based on length and dried sweet potatoes peel do not contain minerals and vitamins to counter the effects of the anti-nutrients.

This study concurred with work of Omoregie *et al* (2009) who carried out empirical examination on the growth-based performance of the Tilapia *Oreochromis niloticus* which were fed with feed of different levels of sweet potato peels. Analysis of the results of plasma glucose and plasma protein revealed that there were no deleterious effects recorded in the test fish due to the dietary inclusion of the sweet potato peel and the results revealed that the fish samples could tolerate up to 15% level of inclusion of sweet potato peel due to presence of some anti-nutrient in the peel. The outcome of current study also aligned with work of Solomon *et al* (2015) who reveals from their study that sweet potatoes peel can completely be used to replace Maize at 30% inclusion level, finally, the results concurred with study carried by Agubosi *et al.,* (2022) on the nutrition value of sweet potato peels dried using air-drying and sun-drying methods and their results revealed that dried sweet potatoes peel contained tolerable amount of anti-nutrients such as flavonoids, phenols, alkaloids, saponins, trypsin, phytate, cyanogenic glycosides, condensed tannins, hydrolysable tannins and anthocyanins

The results of the current study on the impact of the feed sample containing only dried watermelon peels on the growth performance of tilapia fingerling revealed that the feed sample formulated by including only dry watermelon peels is better in improving the growth indictors based on length of the fish samples because watermelon peel contains good amount of minerals and vitamins that are responsible for improving growth such as calcium and magnesium but the feed sample is limited in improving the growth indicators based on weight because it contain small amount caloric and carbohydrates responsible for improved growth based on weight

This outcome of this current study on growth performance of dry watermelon peel concurred with results of Oladipupo andSalami (2020) revealed inclusion of watermelon peel in feed of catfish is ideal for improving their growth parameters., and also the work Iheanacho *et al* (2018) who carried out study to ascertain the impact of inclusion of different amount of peel of water melon on growth juveniles of *Oroechromis niloticus* and their results revealed that dried peel of water melon is suitable as inclusion in the fish feed. The results from this study agreed with results of Adejumo *et al.,* (2015) which revealed that water melon is full of vitamins line vitamin C, vitamin B6 and vitamin A and numerous minerals like copper, zinc, iron, magnesium, calcium, potassium and many other essential minerals required for growth and for neutralizing the side effect of anti-nutrients.

The results of the current study on the impact of the feed containing both the dried sweet potatoes peels and watermelon peels on the growth performance of tilapia fingerling revealed that the feed sample formulated by including both dry sweet potatoes and dry watermelon peels is better in improving both the growth indicators based on length and did analysis based on weight because it contains both good amount of minerals and vitamins to improve growth indicators based on length by reducing the activities of the anti-nutrients in sweet potatoes peel and good amount of caloric to improve the growth indicators based on weight and compensate for small amount of caloric in dry watermelon peel responsible for growth based on weight. This compensation made by inclusion of both the dried sweet potatoes peels and watermelon peels in the same feed helped to significantly improve the growth performance indicators based on both length and weight of the fish samples fed with the feed sample.

These results correspond with the results of Omokore and Oluwafemi (2020) who concluded that the feed formulated with dry watermelon and sweet potatoes peel contain numerous bioactive chemicals and nutrients that can support growth of animals and it could be used as feed for other animal including tilapia fish with no negative impact in their overall growth performance. Thus, being that this reviewed empirical literature is the only empirical work, to the researchers best of knowledge, which examined the impact of combining the two peels as inclusion in feeds and its possible impact on growth parameters of animal, it became necessary to examine the combination of the same two peels for tilapia fish feed formation, basically to improve their growth performance and reduce cost of feeds.

These results agreed with the results from the study of Omoregie *et al* (2009) who examined the growth-based performance of the Tilapia *which* were fed with feed of different levels of sweet potato peels and the results revealed the best increase in weight of the fish samples was achieved with the control diet and the best specific growth rate (SGR) and digestibility were also obtained in the fish fed the control diet. This was attributed to presence of anti-nutrient the feed sampled with dry sweet potatoes inclusion which is not present in the control feed. Similar outcome was also reported by Faramarzi *et al.,* (2012) who carried out experiment study to ascertain the performance of the Catfish fed with different levels of processed dried potato peels and the results revealed that the greatest increase in weight of the fish was noticed with fish samples fed with the control feed and the best SGR and digestibility values were noticed in fish that were fed with control feed while fish fed using feed that contain highest amount of sweet potatoes peel recorded the lowest SGR and digestibility. This could also be linked to presence of anti-nutrient in sweet potatoes peel which tends to hinder growth.

However, the best performance shown by control feed sample could also be attributed to the facts that the control feed has all the necessary nutrient with little or no anti-nutrition therefore a small amount of the feed contain enough nutrient that would produce a unit increase in the weight of the fish samples fed with feed while the lowest growth performance observed in feed with only sweet potatoes peel could be attributed to presence of anti-nutrition agent and limited minerals and vitamins in the feed which tend to hinder the feed absorption thus, more of the feed is required to generate a unit increase in the body weight of the feed samples fed with the feed. However, the combination of sweet potatoes peel to water melon made a better compensation by introducing the mineral and vitamins that counters the activities of the anti-nutrient thereby improving the feed utilization of the fish sample as compare to feed with only sweet potatoes peels.

Conclusions and Recommendations

Based on the findings of this study, the following conclusions were drawn;

1. Dried water-melon and sweet potato peels are suitable as inclusion in formulating fish feed for tilapia fingerlings.
2. Using only dried sweet potato peel as inclusion in formulation of fish feed for tilapia will provide significant improvement on their growth performance based on weight with little improvement on growth performance based on length.
3. Using only dried water-melon peels as inclusion in formulation of fish feed for tilapia will provide significantly improvement on their growth performance based on length with little improvement on growth performance based on weight.

4. Using both dried water-melon peels and dried sweet potatoes peels as inclusion in formulation of fish feed for tilapia will provide significant improvement on their growth performance based on length and weight.
5. However, the feed sample without inclusion of both dried water-melon peels and dried sweet potatoes peels will still be best in improving the growth performance of the fish samples based on both length and weight.

Based on the findings and conclusions of this study it is therefore recommended that;

1. Fish farmers should be encouraged to formulate their fish feed by including both dried water-melon peels and dried sweet potatoes peels as such will improve the growth performance of their fish and also reduce the cost of fish feed.
2. Fish farmers should be discouraged from using only sweet potatoes peels or only water melon peels as inclusion in formulating their fish feed for tilapia because such feeds will be lacking in some basic growth-based nutrients which could lead to distorted growth of their fish.

Reference

Adejumo BA, Olorunsogo ST and Njoku CB (2015). Qualities of watermelon seed oil extracted at different moisture content. *International Journal of Advanced Engineering Research and Technology,* 3(3): 97-100.

Agubosi. O. C. P., Imudia F.D and Alagbe. J. O (2022). Evaluation of the Nutritive Value of Air-Dried and Sun-Dried Sweet Potato (Ipomoea Batatas) Peels, *European Journal of Life Safety and Stability*, 14(2) 342-356 www.ejlss.indexedresearch.org

Collins J.K, Wu G., Perkins-Veazie P., Spears K., Claypool P.L change to and Baker RA (2007). Watermelon consumption increases plasma arginine concentrations in adults. *Nutrition* 23(3):261-266.

FAO. (2011). Fisheries and Aquaculture Department. *National Aquaculture Sector Overview Uganda. Food and Agriculture Organization of the United Nations, Rome, Italy*.

FAO. (2021). Production of sweet potato top 10 producers 2019. Accessed via http://www.fao.org/faostat/en#data/Qcl/visualize on September 29,2021.

Faramarzi, M, Kiaalvandi. M.L.S and Iranshahi F. (2012) Influences of Different Levels of Sweet Potato Peels on Growth and Feeding Parameters and Biochemical Responses of Cyprinus carpio (Cyprinidae). *American-Eurasian Journal of Agriculture & Environmental Science* 12 (4): 449-455, 2012.

Hrubec T,C, Cardinale J. and Smith S.A (2010). Haematology and plasma chemistry reference intervals for cultured tilapia (*Oreochromis* hybrid), *Veterinary Clinical Pathology*, 29:7-12

Iheanacho S.C., Ikwo I.N., Igweze. N.O., Chukwuidha C Ogueji. E.O and Onyeneke R (2018). Effect of Different Dietary Inclusion Levels of Melon Seed (*Citrullus lanatus*) Peel on Growth, Haematology and Histology of *Oroechromis niloticus* Juvenile. *Turkish Journal of Fisheries and Aquatic Sciences*, 18: 377-384, DOI: 10.4194/1303-2712-v18_3_03

Jauncey K & S Ross A (2010). Guide to Tilapia Feeds and Feeding. *University of Sterling, Scotland.*

Kays S.J (2009) The physiology of yield in the sweet potato. In: JC Bouwkamp (Ed.) Sweet Potato Products - *A Natural Resource for the Tropics, CRC Press, Florida, USA*. 2009.

Lim C., Beames, Eales R.M., Prendergast J.G., Mcleese A.F., Shearer J.M and Higgs. DG (2011) Nutritive values of low and high fibre canola meals for shrimps (*Ipenaeus vannamei*). *Aqua-culture. Nutrition* 3: 269 – 279.

Marconato, A. M., Hartmann, G. L., Santos, M. M. R., Amaral, L. A., Souza, G. H. O., Santos, E. F., and Novello, D. (2020). Sweet potato peel flour in hamburger: effect on physicochemical, technological and sensorial characteristics. *Brazilian Journal of Food Technology, 23*, e2019115. https://doi.org/10.1590/1981-6723.11519

Masudul M. Hoque, and Abdullah I (2015) Drying of Watermelon Rind and Development of Cakes from Rind Powder. *International Journal of Novel Research in Life Sciences*, 2(1):14-21.

Oladipupo T.M and Salami S.R (2020) Effect of dietary inclusion levels of watermelon (*Citrullus lanatus*) peel meal on growth and haematological parameters of *Clarias gariepinus* Juveniles, *International Journal of Fisheries and Aquatic Studies* 8(3), 537-541

Omokore, E.A and Oluwafemi, R.A (2020) Effects of Dried Water Melon and Sweet Orange Peel (DWMOP) Meal Mixture on the Performance and Carcass Characteristics of Growing Rabbits. *United International Journal for Research & Technology* 1(11) 29-34

Omoregie, E., Igoche , L., Ojobe T.O., Absalom K.V and Onusiriuka B.C (2009) Effect Of Varying Levels of Sweet Potato (*Ipomea batatas* peels on Growth, Feed Utilization and Some Biochemical Responses of the Cichlid (*Oreochromis Niloticus), African Journal of Food, Agriculture, Nutrition and development, 9(2)*

Omoregie E & Ogbemudia F.I (2009) Effect of substituting fishmeal with palm kernel on growth and food utilization of the Nile Tilapia, (*Oreochromis niloticus*) *Israeli Journal of Aqua-culture*. 43: 113 – 119.

Omoregie E (2001) Utilization and nutrient digestibility of mango seeds and palm kernel meal by juvenile *Labeo senegalensis* (Antheriniformes: Cyprinidae) *Aqua cultural Reserve*; 32: 681 – 687.

Solomon, S.G., Okomoda, V.T and Oloche, J. A. (2015) Evaluation of Sweet Potato (*Ipomea batatas*) Peel as a Replacement for Maize Meal in the Diet of *Clarias gariepinus* Fingerling. *Fisheries Science 9*(4): 063-068

Sunday, N. U. and Komi, G.W. (2021) Comparative Effects of Feeding of Live Maggot and Vital Feed on the Growth and Survival Rate of *Clarias gariepinus* Fingerlings (Burchell, 1822) *Researchjournali's Journal of Agriculture 8(7) www.researchjournali.com/pdf/5748.pdf*

World Fish Center (2007).The Millennium Development Goals: Fishing for a Future; Brochure No.1709.

EFFECT OF BREED ON PERFORMANCE AND CARCASS CHARACTERISTICS OF THREE BREEDS OF IMPROVED TROPICALLY ADAPTED CHICKENS

J.C. Chinwendu1*, F.O. Ajayi, and B.O. Agaviezor

Department of Animal Science, University of Port-Harcourt

*Corresponding author: chinwendu_jonadab@uniport.edu.ng

ABSTRACT

This study explored the effect of breed on performance and carcass characteristics as well as explored the polymorphisms of the Neuropeptide Y (NPY) gene in three breeds of improved tropically adapted chicken breeds (Funaab-Alpha, Sasso and Noiler). The study was designed as a completely randomized design (CRD) experiment using 100 day old chickens of each of the breeds studied (n=300). The results of the study showed that breed and sex effects were significantly different in some of the performance parameters across the breeds. There were no significant differences (P>0.05) in initial weight, feed intake, feed conversion ratio (FCR) and average daily feed intake (ADFI). The final weight across the three breeds were significantly different (P<0.05) with Sasso having the highest mean value, followed by Noiler and the least being Funaab-Alpha. Carcass characteristics across the breeds showed no significant variations (P>0.05).

Keywords: Breed Effect, Sustainable Poultry Farming, Climate-Resilient Poultry.

INTRODUCTION

The global poultry industry stands at the nexus of meeting the burgeoning demand for high-quality protein, sustaining rural livelihoods, and contributing to food security (Mottet and Tempio, 2017). Poultry, and specifically chicken, has become a dietary staple for people around the world due to its accessibility, versatility, and nutritional value (Korver, 2023). As the world population continues to grow, coupled with changing dietary preferences, the poultry sector faces the challenge of not only meeting escalating demands but doing so sustainably and efficiently (Gu *et al*., 2021).

Amidst the vast array of chicken breeds, those adapted to tropical climates have gained particular significance (Lawal and Hanotte, 2021; Tian *et al*., 2020). Tropical regions, characterized by high temperatures, humidity, and unique disease challenges, present a formidable environment for poultry farming. In response, the concept of improved tropically adapted chicken breeds has emerged, reflecting a strategic approach to address the complexities of tropical conditions(Ahmad, 2018; Oke *et al*., 2021). This study embarks on a comprehensive exploration of the breed effect on the performance of three distinct improved tropically adapted chicken breeds namely, Funaab Alpha, Noiler, and Sasso breeds, seeking to unravel their performance in tropical environments.

Poultry farming has undergone a transformative journey, evolving from backyard subsistence farming to a highly sophisticated and industrialized sector (Gržinić *et al*., 2023). This evolution is propelled by the increased demand for poultry products, driven by population growth, urbanization, and rising incomes (Kleyn and Ciacciariello, 2021). Chickens, in particular, have become the primary focus due to their rapid growth, adaptability, and relatively low environmental footprint compared to other livestock (Alders *et al*., 2018).

In the contemporary landscape, the importance of sustainable and resilient poultry farming cannot be overstated. Climate change, environmental degradation, and disease outbreaks pose significant threats to global food systems (Howard and Huston, 2019). Poultry farming, with its relatively short production cycle and efficient feed conversion, offers a promising avenue for addressing food security concerns (Attia *et al*., 2022). However, realizing this potential requires a keen understanding of how specific chicken breeds respond to diverse environmental conditions, particularly in regions with tropical climates.

Improved tropically adapted chicken breeds represent a proactive response to the challenges imposed by tropical climates. These breeds undergo selective breeding processes to enhance traits such as heat tolerance, disease resistance, and overall adaptability to the specific stressors prevalent in tropical regions (Bamidele *et al*., 2020; Biazen, 2021). The rationale behind developing such breeds is rooted in the recognition that a one-size-fits-all approach to poultry farming is untenable, given the diverse climatic conditions across the globe.

Funaab Alpha, Noiler, and Sasso breeds stand as exemplars of this breeding paradigm, each with unique genetic attributes tailored to thrive in tropical environments. The success of these breeds is not solely defined by their ability to withstand the harsh tropical conditions but also by their capacity to maintain high-performance standards in terms of growth rates, feed efficiency, and overall health (Ajayi, 2010; González *et al*., 2021).

While extensive research (Athrey, 2020; González *et al*., 2021; Neeteson *et al*., 2023) has explored the breed effect in poultry farming, there exists a conspicuous gap in the literature when it comes to the specific challenges posed by tropical environments. Tropical climates introduce unique stressors, including elevated temperatures, high humidity, and an increased prevalence of diseases such as Newcastle disease and avian influenza (Lowen and Steel, 2014; Oke *et al*., 2021). These conditions necessitate a focused investigation into how Funaab Alpha, Noiler, and Sasso breeds respond to these challenges, both in terms of growth performance and overall adaptability.

Moreover, as the world grapples with the implications of climate change, understanding how chicken breeds adapted to tropical conditions can contribute to the broader discourse on climate-resilient agriculture. The insights gleaned from these improved tropically adapted breeds can potentially inform breeding programs globally, guiding the development of poultry breeds with enhanced resilience to a changing climate.

MATERIALS AND METHODS

This study was carried out at the Teaching and Research Farm situated at the Choba campus of the University of Port Harcourt. The study lasted for a period of twenty (20) weeks.

Experimental Birds and Management

A total of 300-day-old birds, 100 of each breed namely: Funaab Alpha, Sasso and Noiler were used for the study. On arrival, the birds were put in separate pens according to their breeds. The initial weight of the birds was sampled from a representative fraction of the flock. The birds were brooded for four weeks after which they were raised to full maturity in a deep litter system. The birds were fed with commercial feed rations with feed and clean water administered *ad libitum*. Vaccination schedule for the birds was also strictly adhered to which includes NDV Lasota and NDV Kamorov with their booster doses as well as fowl pox vaccine administered via wing jabs. The birds were also tagged on their wings at one week of age for individual identification.

Experimental Design

The study was carried out using a factorial design (Breed × Sex). The birds were separated into three pens on arrival according to their breeds, each pen containing one hundred (100) birds of each breed.

Data Collection

Upon arrival, the birds were weighed to determine their initial weight. Thereafter, their weights were recorded at four-week intervals, specifically at the 4th, 8th, 12th, 16th, and 20th week of age. Feed intake was weighed daily and the leftover recorded. At the conclusion of the study, a total of four birds per breed were humanely slaughtered at the age of 20 weeks. The selection process for these specimens was based on their average body weight and sexual characteristics, with the aim of capturing an accurate representation of each breed. Following the removal of internal organs, an assessment of carcass traits was conducted, encompassing live weight, dressing percentage, and the proportional weights of the measured components, such as the breasts, drumsticks, wings, and thighs.

Statistical analysis

Performance and carcass characteristics data were subjected to Analysis of Variance (ANOVA) using Statistical Package for Social Sciences (SPSS) version 27 and mean differences were separated using Duncan multiple range test.

RESULTS

Effect of breed on performance of Funaab-Alpha, Sasso and Noiler

The effect of breed on performance of Funaab-Alpha, Sasso and Noiler is shown on Table 1. The Table shows that there were no significant differences ($P > 0.05$) in initial weight, feed intake, feed conversion ratio (FCR) and average daily feed intake (ADFI). The final weight across the three breeds were significantly different ($P < 0.05$) with Sasso (1528.073 ± 52.17) having the highest mean value, followed by Noiler (1418.82 ± 34.38) and the least being Funaab-Alpha (1325.93 ± 31.20). Weight gain was also significantly different ($P < 0.05$) across the breeds with Sasso (1086.00 ± 44.97) being the highest, followed by Noiler (995.85 ± 29.63) and the least being

Funaab-Alpha (885.98 ± 26.90). Average daily weight gain differed significantly ($P < 0.05$) among the breeds with the highest recorded in Sasso (9.70 ± 0.40), this is followed by Noiler (8.89 ± 0.27) and Funaab-Alpha (7.91 ± 0.24) recorded the least. Feed efficiency was also significantly different ($P < 0.05$) across the breeds with Sasso (62.00 ± 2.55) recording the highest, followed by Noiler(54.62 ± 1.68) and Funaab-Alpha (52.54 ± 1.52) recorded the least.

Effect of sex on performance of Sasso, Noiler and Funaab-Alpha chickens

The effect of sex on performance of Sasso, Noiler and Funaab-Alpha chickens is shown on Table 2. The Table shows that the initial weight between males and females differed significantly ($P < 0.05$) with the males (469.84 ± 11.97) having a higher mean than the females (400.14 ± 8.51). Final weight differed significantly ($P < 0.05$) between both sexes with males having a higher mean (1570.83± 37.94) than the females (1277.72 ± 26.98). Weight gain was significantly different ($P < 0.05$) between both sexes, with a higher mean value recorded for males (1100.99 ± 32.71) than females (877.57 ± 23.26). Feed intake and Average daily feed intake (ADFI) did not differ significantly ($P > 0.05$) between both sexes. The feed conversion ratio (FCR) between both sexes was significantly different ($P < 0.05$) with a higher mean recorded for females (2.13 ± 0.06) than males (1.76 ± 0.09). Average daily weight gain (ADWG) differed significantly ($P < 0.05$) between both sexes with males (9.83 ± 0.29) having higher mean values than females (7.835 ± 0.21). Feed efficiency was also significantly different ($P < 0.05$) between males (62.78 ± 1.85) and females (49.98 ± 1.32).

Effects of breed and sex on the performance of Sasso, Noiler and Funaab-Alpha chickens

The effects of breed and sex on the performance of Sasso, Noiler and Funaab-Alpha chickens is shown on Table 3. The table shows that initial weight of Funaab alpha males (487.03 ± 15.40) was significantly different ($P < 0.05$) from that of Funaab-Alpha females (392.87 ± 12.27), but there was no significant difference ($P > 0.05$) between the initial weight of Funaab-Alpha males (487.03 ± 15.40) and Sasso males (479.6 ± 27.98) as well as Noiler males (442.90 ± 16.43). There was also no significant difference ($P > 0.05$) between the initial weights of Sasso males (479.6 ± 27.98), Noiler males (442.90 ± 16.43), Sasso females (404.54 ± 17.35), Noiler females (403.03 ± 14.17) and Funaab-Alpha females (392.87 ± 12.27).

Final weight of Sasso males (1737.80 ± 88.66) was significantly different ($P < 0.05$) from Sasso females (1318.35 ± 54.99), Noiler females (1333.97 ± 44.89) and Funaab-Alpha females (1180.83 ± 38.88). Final weight of Noiler males (1503.66 ± 52.07) was also significantly different ($P < 0.05$) from Funaab-Alpha female (1180.83 ± 38.88). Final weight of Funaab-Alpha male (1471.03 ± 48.81) was also significantly different ($P < 0.05$) from Funaab-Alpha female (1180.83 ± 38.88). Weight gain was significantly different ($P < 0.05$) across the groups with Sasso males (1258.20 ± 76.43) being significantly different ($P < 0.05$) from Sasso females (913.81 ± 47.40), Noiler females (930.95 ± 38.70), Funaab-Alpha females (787.96 ± 33.52) and Funaab-Alpha males (984 ± 42.08). Weight gain for Funaab-Alpha females (787.96 ± 33.52) was significantly different ($P < 0.05$) from Funaab-Alpha males (984 ± 42.08) and Noiler males (1060.76 ± 44.88). There was no significant difference ($P > 0.05$) for weight gain between Noiler males (1060.76 ± 44.88), Noiler female (930.95 ± 38.70), Sasso female (913.81 ± 47.40) and Funaab-Alpha male (984 ± 42.08).

Feed conversion ratio (FCR) differed significantly ($P < 0.05$) between Funaab-Alpha female (2.23 ± 0.09) and Sasso male (1.45 ± 0.21). There is also a significant difference ($P < 0.05$) between Noiler female (2.13 ± 0.11) and Sasso male (1.45 ± 0.21) for FCR. There was no significant difference ($P > 0.05$) in FCR between Sasso male (1.45 ± 0.21), Sasso female (2.02 ± 0.13), Noiler male (1.99 ± 0.12) and Funaab-Alpha male (1.84 ± 0.12). And there was also no ($P > 0.05$)

significant difference between Funaab-Alpha female (2.23 ± 0.09), Noiler female (2.13 ± 0.11), Sasso female (2.02 ± 0.13), Sasso male (1.45 ± 0.21), and Funaab-Alpha male (1.84 ± 0.12).

Average daily weight gain (ADWG) was significantly different ($P < 0.05$) across the groups with Sasso males (11.23 ± 0.68) being significantly different ($P < 0.05$) from Sasso females (8.16 ± 0.42), Noiler females (8.31 ± 0.35), Funaab-Alpha females (7.04 ± 0.30) and Funaab-Alpha males (8.79 ± 0.38). Average daily weight gain (ADWG) for Funaab-Alpha females (7.04 ± 0.30) was significantly different ($P < 0.05$) from Funaab-Alpha males (8.79 ± 0.38) and Noiler males (9.47 ± 0.40). There was no significant difference ($P > 0.05$) for average daily weight gain (ADWG) between Noiler males (9.47 ± 0.40), Noiler female (8.31 ± 0.35), Sasso female (8.16 ± 0.42) and Funaab-Alpha male (8.79 ± 0.38).

Feed efficiency of Sasso males (71.83 ± 4.33) was significantly different ($P < 0.05$) from Sasso females (52.17 ± 2.68), Noiler females (51.06 ± 2.19) and Funaab-Alpha females (46.73 ± 1.90). Feed efficiency of Noiler males (58.18 ± 2.54) was also significantly different ($P < 0.05$) from Funaab-Alpha females (46.73 ± 1.90). Feed efficiency of Funaab-Alpha males (58.35 ± 2.38) was also significantly different ($P < 0.05$) from Funaab-Alpha females (46.73 ± 1.90).

Effect of breed on the carcass characteristics of Funaab-Alpha, Sasso and Noiler chickens

The effect of breed on the carcass characteristics of Funaab-Alpha, Sasso and Noiler chickens is shown on Table 4. The table shows that there were no significant differences ($P > 0.05$) for live weight, dressed weight, head, neck, breast cut, back cut, shanks, thighs, drumstick, heart, liver, gizzard, wings and dressing percentage across the three breeds. A significant difference ($P < 0.05$) is observed in the shanks with Noiler (86.00 ± 1.41) being significantly higher than Sasso (70.50 ± 2.26) and Funaab-Alpha (73.00 ± 3.63).

Table 1: Effect of breed on performance of Funaab-Alpha, Sasso and Noiler chickens

PARAMETERS	FUNAAB ALPHA	SASSO	NOILER
Initial weight (g)	439.95 ± 9.84	442.07 ± 16.46	422.96 ± 10.85
Final weight (g)	1325.93 ± 31.20^{b}	1528.07 ± 52.17^{a}	1418.82 ± 34.38^{ab}
Weight gain (g)	885.98 ± 26.90^{b}	1086.00 ± 44.97^{a}	995.85 ± 29.63^{a}
Feed intake (g)	1686.37 ± 0.00	1751.73 ± 0.00	1823.39 ± 0.00
FCR	2.04 ± 0.07	1.74 ± 0.12	2.07 ± 0.08
ADWG (g)	7.91 ± 0.24^{b}	9.70 ± 0.40^{a}	8.89 ± 0.27^{a}
ADFI (g)	15.06 ± 0.00	15.64 ± 0.00	16.28 ± 0
FE	52.54 ± 1.52^{b}	62.00 ± 2.55^{a}	54.62 ± 1.68^{ab}

abcd: means with different superscripts across rows are significantly different (p ≤ 0.05).

FCR: Feed conversion ratio; ADWG: Average daily weight gain; ADFI: Average daily feed intake; FE: Feed efficiency

Table 2: Effect of sex on performance of Funaab-Alpha, Sasso and Noiler chickens

PARAMETERS	MALE	FEMALE
Final weight (g)	1570.83± 37.94^{a}	1277.72 ± 26.98^{b}
Initial weight (g)	469.84 ± 11.97^{a}	400.14 ± 8.51^{b}
Weight gain (g)	1100.99 ± 32.71^{a}	877.57 ± 23.26^{b}
Feed intake (g)	1753.83 ± 0.00	1753.83 ± 0.00
FCR	1.76 ± 0.09^{b}	2.13 ± 0.06^{a}
ADWG (g)	9.83 ± 0.29^{a}	7.835 ± 0.21^{b}
ADFI (g)	15.66 ± 0.00	15.659 ± 0.00
FE	62.78 ± 1.85^{a}	49.98 ± 1.32^{b}

^{abcd}: means with different superscripts across rows are significantly different (P ≤ 0.05).

FCR: Feed conversion ratio; ADWG: Average daily weight gain; ADFI: Average daily feed intake; FE: Feed efficiency

Table 3: Effect of breed and sex on performance of Funaab-Alpha, Sasso and Noiler chickens

PARAMETERS	FA×MALE	FA×FEMALE	SA×MALE	SA×FEMALE	NL×MALE	NL×FEMALE
FW (g)	1471.03 ± 48.81^{ab}	1180.83 ± 38.88^{c}	1737.80 ± 88.66^{a}	1318.35 ± 54.99^{bc}	1503.66 ± 52.07^{ab}	1333.97 ± 44.89^{bc}
IW (g)	487.03 ± 15.40^{a}	392.87 ± 12.27^{b}	479.6 ± 27.98^{ab}	404.54 ± 17.35^{b}	442.90 ± 16.43^{ab}	403.03 ± 14.17^{b}
WG (g)	984 ± 42.08^{b}	787.96 ± 33.52^{c}	1258.20 ± 76.43^{a}	913.81 ± 47.40^{bc}	1060.76 ± 44.88^{ab}	930.95 ± 38.70^{bc}
FI (g)	1686.37 ± 0.00	1686.37 ± 0.00	1751.73 ± 0	1751.73 ± 0	1823.39 ± 0.00	1823.39 ± 0
FCR	1.84 ± 0.12^{ab}	2.23 ± 0.09^{a}	1.45 ± 0.21^{b}	2.02 ± 0.13^{ab}	1.99 ± 0.12^{ab}	2.13 ± 0.11^{a}
ADWG (g)	8.79 ± 0.38^{b}	7.04 ± 0.30^{c}	11.23 ± 0.68^{a}	8.16 ± 0.42^{bc}	9.47 ± 0.40^{ab}	8.31 ± 0.35^{bc}
ADFI (g)	15.06 ± 0.00	15.06 ± 0.00	15.64 ± 0.00	15.64 ± 0.00	16.28 ± 0.00	16.28 ± 0.00
FE	58.35 ± 2.38^{ab}	46.73 ± 1.90^{c}	71.83 ± 4.33^{a}	52.17 ± 2.68^{bc}	58.18 ± 2.54^{ab}	51.06 ± 2.19^{bc}

^{abcd}: means with different superscripts across rows are significantly different ($P \leq 0.05$).

FW: Final weight; IW: Initial weight FCR: Feed conversion ratio; ADWG: Average daily weight gain; ADFI: Average daily feed intake; FE: Feed efficiency;FA: Funaab Alpha; SA: Sasso; NL: Noiler.

Table 4: Effect of breed on carcass characteristics of Funaab-Alpha, Sasso and Noiler chickens

PARAMETERS	FUNAAB ALPHA	SASSO	NOILER
Live weight (g)	1807.25 ± 20.77	1647.50 ±8 1.38	1737.75 ± 92.08
Dressed weight (g)	1154.25 ± 24.74	1082.50 ± 49.93	1108.50 ± 55.82
Head (g)	56.25 ± 0.48	55.75 ± 1.38	57.25 ± 3.43
Neck (g)	90.00 ± 6.21	82.75 ± 7.73	84.00 ± 5.40
Breast (g)	273.50 ± 5.25	245.00 ± 14.87	257.00 ± 16.83
Back (g)	243.50 ± 3.07	216.00 ± 7.91	220.25 ± 8.96
Shank (g)	73.00 ± 3.63^{b}	70.50 ± 2.26^{b}	86.00 ± 1.41^{a}
Thigh (g)	189.00 ± 14.53	161.75 ± 7.71	160.25 ± 5.54
Drumstick (g)	199.00 ± 4.71	181.75 ± 10.14	197.25 ± 9.80
Heart (g)	7.00 ± 0.41	5.75 ± 0.48	6.00 ± 0.41
Liver (g)	31.25 ± 1.03	27.00 ± 0.71	29.75 ± 3.33
Gizzard (g)	46.50 ± 5.17	47.75 ± 1.84	49.00 ± 4.30
Wings (g)	156.50 ± 5.85	146.00 ± 8.26	155.00 ± 4.42
Dressing percentage (%)	63.8465 ± 0.64	65.7540 ± 0.78	63.8275 ± 0.51

^{abcd}: means with different superscripts across rows are significantly different ($P \leq 0.05$).

DISCUSSION

Effect of breed on performance

This study observed a significant effect of breed on performance of the different chicken breeds. Final weight at 20 weeks differed significantly between Sasso (1528.07g) and Funaab-Alpha (1325.93g) with Noiler (1418.82g) being intermediate. These results are similar to those of (Olayemi *et al*., 2016), who found that the Sasso chicken had a higher average body weight at 8 weeks (1288g) compared to the Noiler (1067g) and FUNAAB Alpha (1172g). (Salako *et al*., 2020) also found that the Sasso chicken (1310g) had a higher average body weight than the Funaab-Alpha (1199g) and Noiler (1076g). (Ayo-Ajasa *et al*., 2015) on the other hand found that the Noiler had a higher average body weight at 8 weeks (1093g) compared to the FUNAAB Alpha (1022g) and Sasso (981g) having the lowest body weight. These differences observed could be attributed to genetic differences as well as biotic and abiotic factors of the environment.

The Funaab-Alpha differed significantly from the Sasso and Noiler in terms of weight gain (TWG and ADWG) in this study, with no significant distinction between the Sasso and Noiler chickens. (Olugbemi *et al*., 2012) obtained similar results when he compared the growth performance of these three chicken breeds under similar conditions. He found that Sasso chicken had the highest body weight gain, followed by Noiler and Funab Alpha. (Ojedapo *et al*., 2018) also compared the growth performance of these three chicken breeds under similar management and feeding conditions over a period of 12 weeks and found that that Sasso chicken had the highest body weight gain followed by Noiler and Funab Alpha. Other authors have also reported higher weight gains in the Sasso chicken compared to the Noiler and Funaab-Alpha chickens (Adeyemi *et al*., 2019; Onunkwo *et al*., 2018).

There was no significant difference in the FCR amongst the different breeds in this study although higher means for FCR were recorded for the Noiler (2.07), followed by Funaab-Alpha (2.04) and Sasso (1.74). Sasso and Funaab-Alpha breeds have been reported to have lower FCR values compared to Noiler birds. For example, in a study by (Ogunwole *et al*., 2021), Noiler birds had an FCR range of 2.39 to 2.61 while Sasso birds in a study by (Elangovan *et al*., 2020) had a range of 1.65 to 1.95 and FUNAAB Alpha birds in a study by (Adeyemi *et al*., 2019) had a range of 1.80 to 2.20. In another study by (Bawa *et al*., 2019), Sasso and FUNAAB Alpha birds had significantly lower FCR values than Noiler birds. These studies also suggest a higher feed efficiency in the Sasso in comparison with the Noiler and Funaab-Alpha. This is in line with the findings of this study which showed a significant difference in the feed efficiency of the different breeds with Sasso having the highest, followed by Noiler and Funaab-Alpha.

The breed differences observed in the performance of these indigenous breeds could be as a result of genetic differences and improvements over time, nutrition, management practices, environmental factors or even interactions between these factors.

Effect of sex on performance

The present study found that there was a significant difference between the performance of male and female chickens used in this study. The males had higher weight gains as well as better feed conversion ratio and efficiency. Many other authors have also obtained similar results. For example, (Omeke *et al*., 2020) compared the growth performance and feed efficiency of Sasso, Noiler, and Funaab Alpha chickens reared under intensive management conditions. The researchers found that male chickens in all three breeds "had significantly higher body weight gain and better feed conversion ratio than females". (Ogunwole *et al*., 2018) also compared the "growth performance and carcass characteristics of Sasso and Noiler chickens reared under different management conditions and discovered that male chickens in both breeds had significantly higher body weight gain and better feed conversion ratio than females". Another study by (Oluwafemi *et al*., 2017) compared the growth performance and carcass characteristics of Sasso, Noiler, and Funaab Alpha chickens reared under free-range management conditions. The researchers found that male chickens had "higher body weight gain and better feed conversion ratio" than females in all three breeds.

The better performances observed in male chickens in comparison to the females even under different managements conditions asserts that sexual dimorphism plays a role in these observed differences (Singh and Yadav, 2019).

Effect of interaction between breed and sex on performance

This study observed a significant effect of interaction of breed and sex on performance. Notable variation is evident in the Sasso male when compared to the Funaab-alpha female in terms of final weight, weight gain, feed conversion ratio and feed efficiency. Other authors have also reported similar evidences of breed × sex interaction on chicken performance. For instance, a study by (Adedeji *et al*., 2017) on the effect of breed and sex on the growth performance and carcass characteristics of Sasso, Noiler, and Fulani chicken ecotype found a significant breed and sex interaction effect on body weight gain and feed intake. (Adeyemo *et al*., 2020) in a study to investigate the effects of "breed, sex and dietary protein levels on the growth performance and nutrient utilization of broiler chickens" reported a significant interaction between breed and sex in determining the body weight gain of the chickens. These observed differences could be attributed to the additive effects of both breed and sex as well as environmental factors.

Effect of breed on carcass characteristics

Some studies have found that weight of carcass cuts and other carcass characteristics in birds differ along breed lines (Ameen *et al*., 2017; Olanrewaju *et al*., 2016) but this current study found no significant differences in the carcass characteristics of the three breeds studied except for the shank cut weight in which Noiler had a higher mean than Sasso and Funaab-Alpha. These results obtained are similar to those of (Jegede *et al*., 2018) and (Okeudo *et al*., 2020) who found "no significant differences in the carcass characteristics" when they compared different breeds of indigenous chickens.

Fasina *et al*. (2016) also compared the carcass characteristics of two Nigerian indigenous chicken breeds, namely, the Fulani and Yoruba ecotypes, with the commercial Arbor Acres broiler breed. The study found no significant difference in the dressing percentage and carcass weight between the Fulani and Yoruba ecotypes and the Arbor Acres breed.

CONCLUSION

This study demonstrated the effect of breed on performance and carcass characteristics in three breeds of improved tropically adapted chicken breeds. This study showed that breed and sex effects were significantly different in some of the performance parameters across the breeds. There were no significant differences in initial weight, feed intake, feed conversion ratio (FCR) and average daily feed intake (ADFI). The final weight across the three breeds were significantly different with Sasso having the highest mean value, followed by Noiler and the least being Funaab-Alpha.

REFERENCES

Adedeji, T. A., Alimi, Y. A., and Obiyan, R. I. (2017). Effect of breed and sex on the growth performance and carcass characteristics of Sasso, Noiler and FUNAAB Alpha chickens. *International Journal of Livestock Production*, *8*(6), 70–76.

Adeyemi, O. A., Adeyemi, G. O., Ojedapo, L. O., and Oso, A. O. (2019). Comparative Growth Performance of Three Nigerian Chicken Ecotypes Reared in the Humid Tropical Environment. *International Journal of Poultry Science*, *18*(7), 330–335.

Adeyemo, G. O., Akinbamijo, O. O., and Oluwatosin, A. B. (2020). Effects of breed, sex and dietary protein levels on the growth performance and nutrient utilization of broiler chickens. *Agricultural Science and Practice*, *7*(1), 28–36.

Ahmad, R. (2018). Tropical Environments. In K. Thankappan, *Selective Neck Dissection for Oral Cancer* (pp. 1–5). Springer International Publishing. https://doi.org/10.1007/978-3-319-12127-7_285-1

Ajayi, F. O. (2010). Nigerian Indigenous Chicken: A Valuable Genetic Resource for Meat and Egg Production. *Asian Journal of Poultry Science*, *4*(4), 164–172. https://doi.org/10.3923/ajpsaj.2010.164.172

Alders, R. G., Dumas, S. E., Rukambile, E., Magoke, G., Maulaga, W., Jong, J., and Costa, R. (2018). Family poultry: Multiple roles, systems, challenges, and options for sustainable contributions to household nutrition security through a planetary health lens. *Maternal and Child Nutrition*, *14 Suppl 3*(Suppl 3), e12668. https://doi.org/10.1111/mcn.12668

Ameen, S. A., Omar, M. A., Mohammed, K. I., Muneer, M. A., and Ba-Omar, T. A. (2017). Detection of genetic diversity of the neuropeptide Y gene in four Saudi chicken breeds. *Journal of the Saudi Society of Agricultural Sciences*, *16*(3), 245–250.

Athrey, G. (2020). Poultry genetics and breeding. In *Animal Agriculture* (pp. 317–330). Elsevier. https://doi.org/10.1016/B978-0-12-817052-6.00018-5

Attia, Y. A., Rahman, M. T., Hossain, M. J., Basiouni, S., Khafaga, A. F., Shehata, A. A., and Hafez, H. M. (2022). Poultry Production and Sustainability in Developing Countries under the COVID-19 Crisis: Lessons Learned. *Animals: An Open Access Journal from MDPI*, *12*(5), 644. https://doi.org/10.3390/ani12050644

Ayo-Ajasa, O. Y., Oke, U. K., Sanwo, K. A., and Oyedipe, E. O. (2015). Comparative evaluation of growth performance and haematological indices of three commercial meat-type chickens in the humid tropics. *Livestock Research for Rural Development*, *27*(8), 159–163.

Bamidele, O., Sonaiya, E. B., Adebambo, O. A., and Dessie, T. (2020). On-station performance evaluation of improved tropically adapted chicken breeds for smallholder poultry production systems in Nigeria. *Tropical Animal Health and Production*, *52*(4), 1541–1548. https://doi.org/10.1007/s11250-019-02158-9

Bawa, G. S., Ayoade, J. A., Umaru, H. A., Saliu, A., and Bawa, E. K. (2019). Growth performance, carcass characteristics and haematology of Sasso, Noiler and FUNAAB Alpha chickens in the derived savanna zone of Nigeria. *Agricultural Science and Technology*, *11*(3), 52–59.

Biazen, A. (2021). *Comparative performance evaluation of local and tropical adapted exotic breeds of chickens in Ethiopia*. https://doi.org/10.13140/RG.2.2.21730.61123

Elangovan, A. V., Kadirvel, G., Sundaresan, A., and Gowtham, K. S. (2020). Feed conversion ratio and growth performance of Sasso broilers fed with different levels of methionine and lysine. *Veterinary World*, *13*(1), 85–89.

Fasina, Y. O., Adenowo, T. K., Oyelade, J. O., Oduwole, O. O., and Ikeobi, C. O. (2016). Neuropeptide Y gene polymorphism and association with growth and carcass traits in Nigerian indigenous chickens. *Journal of Animal Science and Technology*, *58*, 1–8.

González Ariza, A., Arando Arbulu, A., Navas González, F. J., Nogales Baena, S., Delgado Bermejo, J. V., and Camacho Vallejo, M. E. (2021). The Study of Growth and Performance in Local Chicken Breeds and Varieties: A Review of Methods and Scientific Transference. *Animals: An Open Access Journal from MDPI*, *11*(9), 2492. https://doi.org/10.3390/ani11092492

Gržinić, G., Piotrowicz-Cieślak, A., Klimkowicz-Pawlas, A., Górny, R. L., Ławniczek-Wałczyk, A., Piechowicz, L., Olkowska, E., Potrykus, M., Tankiewicz, M., Krupka, M., Siebielec, G., and

Wolska, L. (2023). Intensive poultry farming: A review of the impact on the environment and human health. *Science of The Total Environment*, *858*, 160014. https://doi.org/10.1016/j.scitotenv.2022.160014

Gu, D., Andreev, K., and Dupre, M. E. (2021). Major Trends in Population Growth Around the World. *China CDC Weekly*, *3*(28), 604–613. https://doi.org/10.46234/ccdcw2021.160

Howard, C., and Huston, P. (2019). The health effects of climate change: Know the risks and become part of the solutions. *Canada Communicable Disease Report = Releve Des Maladies Transmissibles Au Canada*, *45*(5), 114–118. https://doi.org/10.14745/ccdr.v45i05a01

Iyayi, E. A., Sola-Ojo, F. E., and Igwebuike, J. U. (2014). Genetic variation of neuropeptide Y gene in Nigerian indigenous chickens. *Genetics and Molecular Research*, *13*(1), 1259–1266.

Jegede, A. V., Yakubu, A., and Imumorin, I. G. (2018). Association of neuropeptide Y gene polymorphism with body weight and linear body measurements in Nigerian indigenous chickens. *International Journal of Livestock Research*, *8*(10), 130–137.

Kleyn, F. J., and Ciacciariello, M. (2021). Future demands of the poultry industry: Will we meet our commitments sustainably in developed and developing economies? *World's Poultry Science Journal*, *77*(2), 267–278. https://doi.org/10.1080/00439339.2021.1904314

Korver, D. R. (2023). Review: Current challenges in poultry nutrition, health, and welfare. *Animal*, *17*, 100755. https://doi.org/10.1016/j.animal.2023.100755

Lawal, R. A., and Hanotte, O. (2021). Domestic chicken diversity: Origin, distribution, and adaptation. *Animal Genetics*, *52*(4), 385–394. https://doi.org/10.1111/age.13091

Lowen, A. C., and Steel, J. (2014). Roles of humidity and temperature in shaping influenza seasonality. *Journal of Virology*, *88*(14), 7692–7695. https://doi.org/10.1128/JVI.03544-13

Mottet, A., and Tempio, G. (2017). Global poultry production: Current state and future outlook and challenges. *World's Poultry Science Journal*, *73*(2), 245–256. https://doi.org/10.1017/S0043933917000071

Neeteson, A.-M., Avendaño, S., Koerhuis, A., Duggan, B., Souza, E., Mason, J., Ralph, J., Rohlf, P., Burnside, T., Kranis, A., and Bailey, R. (2023). Evolutions in Commercial Meat Poultry Breeding. *Animals*, *13*(19), 3150. https://doi.org/10.3390/ani13193150

Ogunwole, O. A., Adeyemi, O. A., Sogunle, O. M., Adeyemi, S. A., and Adelodun, S. T. (2018). Growth performance and carcass characteristics of Sasso and Noiler chickens reared under different management conditions. *Journal of Agricultural Science*, *10*(2), 31–39.

Ogunwole, O. A., Adeyemo, G. O., Adejumo, I. O., and Adejumo, M. K. (2021). Growth performance, carcass yield, and meat quality of Noiler chickens fed different dietary protein levels. *Animal Nutrition and Feed Technology*, *21*(1), 65–75.

Ojedapo, L. O., Adeyemo, G. O., Adeyemi, O. A., Oso, A. O., and Adesina, G. T. (2018). Comparative Growth Performance of Sasso, FUNAAB-Alpha and Noiler Chickens Reared under Humid Tropical Environment. *Nigerian Journal of Animal Science and Technology*, *1*(1), 20–27.

Oke, O. E., Uyanga, V. A., Iyasere, O. S., Oke, F. O., Majekodunmi, B. C., Logunleko, M. O., Abiona, J. A., Nwosu, E. U., Abioja, M. O., Daramola, J. O., and Onagbesan, O. M. (2021). Environmental stress and livestock productivity in hot-humid tropics: Alleviation and future perspectives. *Journal of Thermal Biology*, *100*, 103077. https://doi.org/10.1016/j.jtherbio.2021.103077

Okeudo, N. J., Okoro, V. M., and Ikeobi, C. O. (2020). Association of polymorphism in the neuropeptide Y gene with growth and carcass traits in Nigerian indigenous chickens. *International Journal of Poultry Science*, *19*(6), 296-302.

Olanrewaju, H. A., Purswell, J. L., Collier, S. D., Branton, S. L., and Maslin, W. R. (2016). Influence of darkling beetle larvae on broiler performance, gut microflora, and litter moisture under commercial conditions. *Poultry Science*, *95*(10), 2263–2271.

Olayemi, A. O., Amao, S. R., Oladunjoye, I. O., and Ojedapo, L. O. (2016). Comparative growth performance, carcass characteristics and haematology of three commercial meat-type chickens raised under intensive system in a sub-humid zone of Nigeria. *Bulletin of Animal Health and Production in Africa*, *64*(4), 421–433.

Olugbemi, T. S., Mutayoba, S. K., and Lekule, F. P. (2012). Performance and carcass characteristics of broiler chickens fed diets containing varying levels of Moringa oleifera leaf meal. *International Journal of Poultry Science*, *11*(8), 546–550.

Oluwafemi, R. A., Sonaiya, E. B., and Daramola, J. O. (2017). Growth performance and carcass characteristics of three Nigerian indigenous chicken breeds and the Sasso T44 under free-range system. *International Journal of Livestock Production*, *8*(1), 1–7.

Omeke, S. O., Ezieshi, E. V., Okoli, I. C., and Emelue, G. U. (2020). Comparative growth performance and feed efficiency of some strains of broiler chickens under intensive management system. *Journal of Agricultural Science*, *12*(3), 9–16.

Onunkwo, D. N., Odo, B. I., Uchegbu, M. C., Okoro, V. M., and Ikeobi, C. O. N. (2018). Comparative Growth Performance and Carcass Characteristics of Sasso, Noiler and FUNAAB-Alpha Chickens. *International Journal of Livestock Research*, *8*(3), 122–130. https://doi.org/doi: 10.5455/ijlr.20180110025255

Salako, A. E., Adeleke, M. A., Olanrewaju, H. A., Olabode, A. O., and Bamgbose, A. M. (2020). Comparative evaluation of growth performance and carcass characteristics of four strains of meat-type chickens in the humid tropics. *Nigerian Journal of Animal Production*, *47*(2), 184–190.

Singh, R., and Yadav, A. S. (2019). Effect of sex on growth performance of chicken: A review. *International Journal of Livestock Research*, *9*(3), 73–85.

Tian, S., Zhou, X., Phuntsok, T., Zhao, N., Zhang, D., Ning, C., Li, D., and Zhao, H. (2020). Genomic Analyses Reveal Genetic Adaptations to Tropical Climates in Chickens. *iScience*, *23*(11), 101644. https://doi.org/10.1016/j.isci.2020.101644

OPERATIONS AND CHALLENGES OF ECOTOURISM DESTINATIONS IN SELECTED STATES OF SOUTH EASTERN NIGERIA

[1]Okeke A.N., [2]Ijeomah H.M. and [2]Odunlami S.S

[1]Department of Forestry and Wildlife Technology, Federal University of Technology Owerri, Imo State, Nigeria. E-mail: angela.okeke503@gmail.com**. Phone :+23408060690465**

[2]Department of Forestry and Wildlife Management, University of Port Harcourt, East-West Road, Choba, P.M.B 5323 Port Harcourt, Rivers State, Nigeria. Phone: E -mail: henry.ijeomah@uniport.edu.ng

Abstract

This paper assesses the operations and challenges of ecotourism in selected destinations of South Eastern. Thesedestinations include: Agulu/Nanka erosion site and Ogbunike caves from Anambra state, Nekede zoo and Urashi river source from Imo state, Oferekpe waterfall and Okposi salt lake from Ebonyi state.Three sets of well-structured questionnaires (A,B and C) was used to collect the data. Questionnaire 'A' was administered to 50% of the total number of household in Agulu/Nanka (51), Ogbunike (42), Nekede (48), Dikenafai (54), Oferekpe (40) and Okposi(45), making a total of 280 household respondents. Another set 'B' was administered on 50 tourists from each site and 'C' was administered to 100% of staff respondents in Agulu/Nanka (18), Ogbunike (10), Nekede (24), Dikenafai (15), Oferekpe (8) and Okposi (12). Data collected were subjected to simple descriptive analysis. The results showed that the highest respondents on age (29.24%) fell into the age bracket (36-45) years, while the least (06.30%) were >60 years. The sex ratio was (67.47%) male and (32.53%) female, (46.48%) were married, (50.37%) were unmarried and (03.30%) were divorced. The tourists reception was warm in Agulu/Nanka erosion site (46.00%), Ogbunike caves (38.00%), Urashi river source (64.00%) and Okposi salt lake (60.00%) while indifference (54.00%) at Nekede zoo and poor (62.00%) at Oferekpe water fall. Though the facilities were inadequate in all the sites but majority of the tourist indicated interest to repeat visit. The reasons for protecting eco-destination at Agulu/Nanka (44.83%) and Ogbunike (40.38%) site is tourism, Nekede zoo (43.55%) and Okposi salt (38.46%) lake is biodiversity conservation, cultural festival at Urashi (46.88%) and economic value (35.29%) at Oferekpe waterfall. The way of protecting destination in Agulu/Nanka site is planting trees (52.11%) taring of road (29.63%) at Ogbunike, molding monuments (30.19%) at Nekede zoo, building steps (64.06%) at Urashi river source, bush clearing (50.94%) at Oferekpe waterfall and community rules (40.74%) at Okposi salt lake. The challenges include deforestation at Agulu/Nanka, illegal hunting in Ogbunike caves, empty cages at Nekede zoo, lack of tour guards at Dikenafai, far distance at Oferekpe and crude method of salt production at Okposi salt lake. Also, it suggested publicity as a way of improving sustainable ecotourism in the study destinations.

Keywords: Ecotourism destinations, Conservation, Travel.

INTRODUCTION

The benefits a country or region derives from ecotourism depend largely on the quality of services, tourists inflow, frequency of visitation, caliber of tourists visiting eco-destinations and tourists expenditure pattern (Ijeomah and Okoli, 2016). This implies that the desired constant increases in level of benefits derived from ecotourism in a particular area depend largely among other factors on the rate of operations carried out in eco-destinations (Ijeomah, 2012). Tourism virtues are environment specific, as what attracts people differs from one person to another as influenced by variations in ecological, social, economic and /or cultural background; hence the value of a tourism site depends on the popularity of the tourism features as identified by tourists (Ijeomah, 2007; Ijeomah *et al*, 2007).

The world is full of natural resources that people exploit and appreciate but it is important to use these resources in a sustainable manner so that we can enjoy them and also make it possible for our future generation to enjoy it. (IUCN, 1980). South Eastern Nigeria is rich in tourist destinations especially the community and government managed sites which makes her an ideal destination for ecotourism. Many activities are going on in these eco-destinations other than the main purpose and objective of establishing the sites. Some sites are for the purpose of education or for medical purpose (Guerra *et al*., 2015). Others are for cultural activities or exhibiting purposes while others are for conservation (Idumah *et al*, 2009). Many of these additional activities are carried out in ecodestinations because some of these destinations are fast losing their popularity (Kusler, 1991). (Oluwakemi and Jonathan, 2017) suggested that any other activities carried out in the ecodestination will be carefully done, taking precautions not to change the initial objective and integrity of the ecosystem; which produces economic opportunities to the local populace (Wood, 1999). Ecotourism practices looks at all the impacts of tourism, either positive or negative with the aim to maximize the positive and minimize the negative impacts (Nchor and Asuk, 2018). The United Nation Environment Program (UNEP) and World Tourism Organization (WTO) want ecotourism activities to be activities that take full account of the current and future.

Some activities like cultural, educational or conservation depend on the management of the site. Some of these attractive sites are managed by government, NGO or host communities while some of these locations have been constructed with tourists in mind, others have yet to be fully utilized

(Ogunjinmi, 2015). Also, most of these ecotourism sites in south east are located in the rural communities that support their livelihood on these recreational and cultural activities (Okani and Akade, 2002). Government and the host communities will need to actively participate in all decision-making processes to keep these activities from polluting the destination (Adetola, 2015).

Some of the cultural activities like ‘ogba day’ in Ogbunike caves will bring about people knowing the site. Limiting these activities in some of these sites will reduce the number of tourists visiting the place (Nwosu, 2006). As a result, the study also intends to evaluate the issues that will prevent continued ecotourism site development in South-Eastern Nigeria (Okani, 2002).

However, the various methods used in managing these destinations should be tourist and environmental friendly, because these activities is an effective tool for sustainable development (Okpoko and Okpoko, 2002). If welcoming strategies are poor, tourists will not like to visit such sites again because good management strategies improve economic development (Brıassoulis, 2002).

Some of these activities typically occur in community managed sites. Ekechukwu (2006) said that it should contribute to the conservation or preservation of such sites, other than damage to the environment (Fennell, 1999). Since ecotourism is environmentally friendly and responsible visitation and travel to relatively undamaged or undisturbed natural areas, to appreciate and enjoy nature including any cultural features that promotes and encourages conservation, visitor impact and local activities should be negatively low (Diamantis, 2010). These activities should be educative and provides for beneficially active socio-economic involvement of the local populations (IUCN, 2002). Ecotourism activities could have less negative and more positive impact in an environment. The negative impacts of these activities to a destination includes; damage to the natural environment, economic leakage and overcrowding. While the positive impacts includes; preservation of cultural heritage, job creation, wildlife preservation, landscape restoration, and more (UNEP and WTO, 2005).

Ecotourism activities creates opportunity for economic growth. In fact, these economic opportunities of ecotourism also led to the generation of support for wildlife conservation from traditional in private and public sector institutions (Christie *et al*, 2014) Ecotourism activities has also tremendously enhanced community wellbeing, support and development for wildlife conservation in communities living together. The desired sustained increase in the level of economic benefits derived from ecotourism operations in a particular area depends largely among other factors, the level of development in tourism destinations which is at a very low ebb in state and identification of potential ecotourism resources (Sabele, 2010).

Many of the challenges of ecotourism destinations in South Eastern Nigeria were unknown and even the known ones are not well addressed (Umar, 2022). These specific challenges were drawing the progress of the destinations backward. If the major specific development challenges in the destinations are not identified and addressed, ecotourism development in the South East can hardly be improved and sustained. This study therefore assesses the operations strategies and challenges relevance to selected ecotourism destinations in South Eastern Nigeria.

METHODOLOGY

3.1: Study Area

The study was carried out in six (6) different eco-tourist sites within three states in South Eastern Nigeria. These sites are: Agulu/Nanka erosion site and Ogbunike caves in Anambra state, Nekede zoological garden and Urashi river source in Imo state, Oferekpe water fall and Okposi salt lake in Ebonyi state. Agulu/Nanka erosion site cuts across Aniocha and Orumba North local government area of Anambra state on latitude 6.1100°N and longitude 7.0222° E. Ogbunike caves is in Oyi Local Government Area located along old Enugu-Onitsha express road and lies on latitude 6.1859° N and longitude 6.9061°E. Nekede zoological garden is in Owerri West local government area located on latitude 5.2559°N and longitude 7.0160°E, while Urashi river source of Dikenafai in Ideator South local government area lies on latitude 5.8089°N and longitude 7.0731°E.

Oferekpe water fall in Ikwo local government area lies on latitude 6.4106°N and longitude 7.2147°E while Okposi salt lake in Ohaozara local government area is located on latitude 6.0472°N and longitude 7.7475°E (Figure 1).

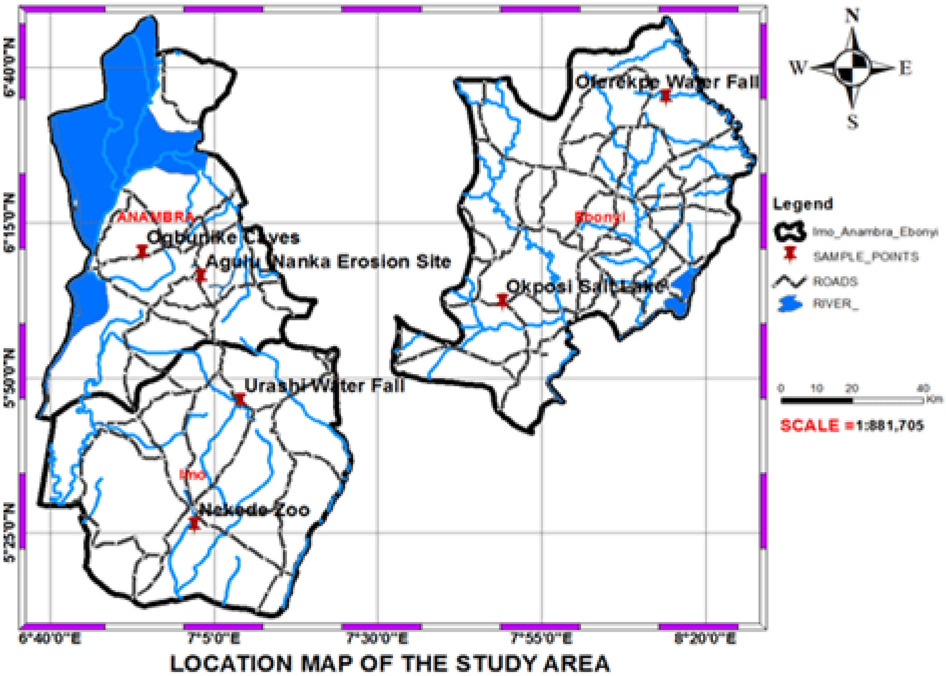


Fig. 1: Map of Eastern Nigeria showing location of the study areas

Data Collection and Analysis

Purposive sampling technique was used to select six ecotourism destinations from south eastern Nigeria. Agulu/Nanka erosion and Ogbunike caves were selected from Anambra state, Nekede zoo and Urashi river source from Imo State while Oferekpe waterfall and Okposi Salt Lake were selected from Ebonyi state. Data for the study were collected through the use of three sets of structured questionnaires administered on the household, staffs and tourists who visited selected sites. The number of households in each identified communities was estimated (based on the average family size of 5-10) as was done by Onuchukwu and Ijeomah (2020) for Southern Nigeria. The host community of each destination was identified. Fifty percent (50) of household size in each community was sampled, 50 tourists from each destination was sampled while all (100%) the staff in each destination was considered for data collection. Data collected were analysed using descriptive statistics in the form of frequency of counts and percentages.

RESULTS AND DISCUSSION

Demographic characteristics of Respondents

The result on Table 1 shows the demographic characteristics of the respondents. In all the sites, the highest respondents on age (29.24%) fell into the age bracket (36-45) years, while the least (06.30%) were >60 years. The sex ratio was (67.47%) male and (32.53%) female. On marital status, (46.48%) were married, (50.37%) were unmarried and (03.30%) were divorced.

The civil servants were (40.50%), self-employed (37.48%) while the least (22.04%) are those that are not working. On years of service, (44.53%) have worked more than 11 years, (40.33%) have worked (6-10) years and the least (15.14%) have worked for (1-5) years. The highest respondents (76.31%) agreed that they have visited the sites more than 3 times, followed by (13.19%) who visited more than 2 times. The least number of respondents (10.49%) have visited just once.

Table 1: Demographic characteristics of Respondents

Variables	Agulu/Na			Ogbunike			Nekede			Dikenafai			Oferekpe			Okposi			Frequency	Percentage (%)
	C	S	T	C	S	T	C	S	T	C	S	T	C	S	T	C	S	T		
AGE																				
20-35	06	08	12	04	02	09	05	04	27	08	--	19	06	--	14	05	--	13	142	21.29
36-45	10	05	18	11	03	21	09	10	12	10	03	12	12	08	19	11	06	15	195	29.24
46-55	15	03	14	13	05	11	12	08	11	11	07	17	11	--	07	14	04	09	172	25.79
56-60	12	02	06	11	--	09	17	02	--	16	05	02	08	--	05	09	02	10	116	17.39
>61	08	--	--	03	--	--	05	--	--	09	--	--	03	--	05	06	--	03	042	06.30
SEX																				
Male	43	13	33	28	07	27	30	18	31	45	15	28	25	08	36	38	--	25	450	67.47
Female	08	05	17	14	03	23	18	06	19	09	--	22	15	--	14	07	12	25	217	32.53
MARITAL STATUS																				
Married	27	04	19	25	03	13	23	09	29	31	08	26	13	02	24	24	12	18	310	46.48
Single	24	13	28	16	07	37	22	14	21	23	07	24	25	06	26	15	--	28	336	50.37
Divorced	--	01	03	01	--	--	03	01	--	--	--	01	02	--	--	06	--	04	022	03.30
OCCUPATION																				
Civil servant	16	18	15	08	10	13	15	24	18	12	15	25	09	08	14	21	12	17	270	40.50
Self employed	22	--	22	24	--	19	21	--	22	23	--	17	18	--	20	18	--	24	250	37.48
Not working	13	--	13	10	--	18	12	--	10	19	--	08	13	--	16	06	--	09	147	22.04
YEARS OF SERVICE																				

1-5 Years	10	05	06	07	01	11	06	03	08	04	02	20	-	-	-	09	02	07	101	15.14
6-10 Years	20	04	12	16	04	15	20	09	27	28	05	13	25	07	25	11	04	24	269	40.33
>11 Years	21	09	32	19	05	24	22	12	15	22	08	17	15	01	25	25	06	19	297	44.53
NUMBER OF SITE VISIT																				
Once	38	-	-	06	-	-	22	-	-	-	-	02	-	-	-	-	-	02	70	10.49
2 times	09	-	16	18	-	06	17	-	14	-	-	04	-	-	01	-	-	03	88	13.19
>3 times	04	18	34	18	10	44	09	24	36	54	15	44	40	08	49	45	12	45	509	76.31

Key: C = Community, S = Staff, T = Tourist

Table 2 shows the tourists reception in selected destinations. The tourists reported that they received warm reception at four destinations of study areas which are; Agulu/Nanka erosion site (46.00%), Ogbunike caves (38.00%), Urashi river source (64.00%) and Okposi salt lake (60.00%). The reception at Nekede zoo was indifference (54.00%), while poor (62.00%) at Oferekpe waterfall.

Table 2: Tourist Reception in Selected Destinations as reported by tourists

NATURE OF RECEPTION	DESTINATOINS					
	Agulu/Nan	Ogbunike	Nekede	Dikenafai	Oferekpe	Okposi
Warm	23(46.00)	19(38.00)	07(14.00)	32(64.00)	04(08.00)	30(60.00
Hostile	12(24.00)	13(26.00)	07(14.00)	10(20.00)	06(12.00)	08(16.00
Indifference	08(16.00)	11(22.00)	27(54.00)	06(12.00)	09(18.00)	09(18.00
Poor	07(14.00)	07(14.00)	09(18.00)	02(04.00)	31(62.00)	03(06.00

Table 3 shows the environmental education strategies preferred by the tourists in these destinations. Agulu/Nanka destination preferred mostly the use of tour guides (45.45%) to take the tourists around. Also, the tourists preferred the use of sign post (35.85%) at Ogbunike caves. They preferred mostly the use of pictures (46.43%) at Nekede zoo, the use of tour guides (61.11%) at Dikenafai destination, the use of sign post (44.00%) at Oferekpe destination and the use of tour guide (72.92%) at Okposi destination.

Table 3: Environmental Education Strategies preferred by the Tourists

STRATAGIES	DESTINATIONS					
	Agulu/Nan	Ogbunike	Nekede	Dikenafai	Oferekpe	Okposi
Tour Guides	25(45.45)	12(22.64)	08(14.29)	33(61.11)	08(16.00)	35(72.92
Sign Post	15(27.27)	19(35.85)	12(21.43)	08(14.82)	22(44.00)	03(06.25
Pictures	09(16.36)	14(26.42)	26(46.43)	08(14.82)	13(26.00)	04(08.33
Fliers and Stickers	06(10.90)	08(15.09)	10(17.86)	05(09.26)	07(14.00)	06(12.50

Table 4 shows reasons for protecting eco-destinations. One of the reasons at Agulu/Nanka erosion site (44.83%), and Ogbunike caves (40.38%) is tourism. Biodiversity conservation (43.55%) at Nekede zoo and Okposi salt lake (38.46%), cultural festival (46.88%) at Urashi river source and economic value (35.29%) at Oferekpe waterfall.

Table 4: Reasons for Protecting Eco-destinations as indicated by household

Eco-destination	Reasons	Frequency	Percentage
Agulu/Nanka erosion	Tourism	23	45.10
	Economic value	14	27.45
	Biodiversity	09	17.65
	conservation		
Ogbunike caves	Tourism	21	50.00
	Economic value	11	26.19
	Cultural festival	07	16.67
	Biodiversity	03	07.14
	conservation		
Nekede zoo	Biodiversity	27	56.25
	conservation	10	20.83
	Economic value	08	16.67
	Tourism	03	06.25
	Cultural festival		
Dikenafai	Cultural festival	30	55.56
	Biodiversity	12	22.22
	conservation	06	11.11
	Economic value	06	11.11
	Tourism		
Oferekpe waterfall	Economic value	18	45.00
	Biodiversity	10	25.00
	conservation	09	22.50
	Cultural festival	03	07.50
	Tourism		
Okposi salt lake	Biodiversity	15	33.33
	conservation	12	26.67
	Economic value	10	22.22
	Tourism	08	17.78
	Cultural festival		

Table 5 shows ways of protecting destinations by host communities. In Agulu/Nanka erosion site, planting trees (52.11%) is one of the ways of protecting the destination. Taring of road (29.63%) at Ogbunike, molding monuments (30.19%) at Nekede zoo, building steps (64.06%) at Urashi river source, bush clearing (50.94%) at Oferekpe waterfall and community rules (40.74%) at Okposi salt lake. Table 6 shows the complains/dislike of tourists in visiting selected sites. Among other things, tourists complained about fearful layers of colored soil in the gully (25.49%) at Agulu/Nanka erosion site, illegal hunting in the caves (21.28%) at Ogbunike, empty cages (28.00%) at Nekede zoo, bush covering the entrance (34.48%) of Urashi at Urashi river source, far distance of the site (32.61%) at Oferekpe waterfall and lack of tour guards (32.65%) at Okposi salt lake

Table 5: Ways of protecting destinations by host communities as indicated by household

Host communities	Ways	Frequency	Percentage
Agulu/Nanka erosion	Tree planting	37	72.55
	Ban on logging	12	23.53
	Creating awareness	02	03.92
Ogbunike caves	Taring road	14	33.33
	Staff training	09	21.43
	Building steps	06	14.29
	Building offices	05	11.90
	Meetings	03	07.14
	Education tourists	03	07.14
	Bush clearing	02	04.76
Nekede zoo	Molding monuments	16	33.33
	Maintaining animals	11	22.92
	Recreational facilities	10	20.83
	Cleaning of environment	07	14.58
	Staff training	04	08.33
Dikenafai	Building steps	41	75.93
	Welfare committee	11	20.37
	Cleaning the environment	02	03.70
Oferekpe waterfall	Bush clearing	17	31.48
	Community rules	10	18.52
	Building road	08	20.00
	Meetings	05	12.50
Okposi salt lake	Community rules	22	48.49
	Lake protection	18	40.00
	Lake fencing	05	11.11

Table 6: Complains/Dislike of Tourists in Visiting Selected Sites

Study sites	Complains	Frequency	Percentage

Agulu/Nanka erosion	Colored soil in the gully	13	25.49
	People still tipping sand around it	15	29.41
	Closeness of erosion to houses	10	19.61
	Erosion not stopping	07	13.73
	Cutting of trees around erosion site	06	11.76
Ogbunike caves	Illegal hunting in the caves	06	14.29
	Sacrifice to gods	05	11.90
	Long steps that lead to the caves	08	19.05
	Expensive gate fee	10	23.81
	Expensive tour guards	05	11.90
	Difficulty in transporting back	06	14.29
	Untidy environment	02	04.71
Nekede zoo	Empty cages	08	16.67
	Sighting sick animals	10	20.83
	Untidy environment	06	12.05
	Expensive gate fee	12	25.00
	Tick wire gaurs blocking view	12	25.00
Dikenafai	Bush covering the entrance	20	37.04
	Un-kept nature of the site	12	22.22
	Not having a tour guard	10	18.52
	Lack of maintenance	12	22.22
Oferekpe waterfall	Far distance of the site	09	22.05
	Logging activities	05	12.05
	Lack of maintenance	06	15.00

	Lack of awareness	12	30.00
	Lack of tour guards	08	20.00
Okposi salt lake	Lack of tour guards	14	31.11
	Bushy environment	08	17.78
	Lack of development	10	22.22
	Crude method of salt making	09	20.00
	Lack of modernization	04	08.89

Table 7 shows the challenges of ecotourism development in the research destinations. One of these challenges at Agulu/Nanka erosion site was weather condition (41.18%). It was during the rainy season that more erosion used to collapse. Slow development (33.33%) was the main challenge at Ogbunike caves, though the community tried to build administrative block that took them many years to complete. Lack of funds (35.42%) was the main challenge at Nekede zoo, lack of development (42.59%) at Urashi river source, bad road (45.00%) at Oferekpe waterfall and crude method (48.89%) of salt making at Okposi salt lake.

Table 7: Challenges of ecotourism development in the research destinations

Destinations	Challenges	Frequency	Percentage
Agulu/Nanka erosion	Weather condition	21	41.18
	Negligence	12	23.53
	Far distance	10	19.61
	Lack of development	05	09.80
	None	03	05.88
Ogbunike caves	Slow development	14	33.33
	Community rules	11	26.19
	None	11	26.19
	Negligence	06	14.29
Nekede zoo	Lack of fund	17	35.42
	Poor maintenance Death of animals Bad road	12	25.00

		10	20.83
		09	18.75
Urashi river source	Lack of development	23	42.59
	Negligence	20	37.04
	Long steps	08	14.81
	Weather condition	03	05.56
Oferekpe waterfall	Bad road	18	45.00
	Far distance	13	32.50
	Poor maintenance	05	12.50
	None	04	10.00
Okposi salt lake	Crude method	22	48.89
	Community rules	09	20.00
	Lack of development	07	15.56
	Bad road	07	15.56

Table 8: Ways of improving ecotourism in the study destinations as indicated by household

Destinations	Ways of improvement	Frequency	Percentage
Agulu/Nanka erosion	Creating awareness	28	54.90

	Construct good roads	13	25.49
	Afforestation	05	09.80
	Reduce access fee	04	07.84
	Tackle security issue	01	01.96
Ogbunike caves	Train tour guards	15	35.71
	Government intervention	12	28.57
	Build restaurants	09	21.43
	Political stability	03	07.14
	Tackle security issue	03	07.14
Nekede zoo	Funding	18	37.50
	Replace dead animals	14	29.17
	Construct good roads	09	29.58
	Reduce access fee	05	10.42
	More development	02	04.17
Urashi river source	Further development	26	48.15
	Good access road	10	18.52
	Train tour guards	07	12.96
	Create awareness	06	11.11
	Establish tourist center	05	09.26
Oferekpe waterfall	Construct good roads	16	40.00
	Advertise the site	08	20.00
	Government intervention	07	17.50
	Train tour guards	05	12.50
	Develop the community	04	10.00
Okposi salt lake	Modern method of salt making	22	48.89

Establish tour center	11	24.44
Train tour guards	10	22.22
Political stability	02	04.44

Table 8 shows the ways of improving sustainable ecotourism in the study destinations. Creating awareness (54.90%) is one of the ways in Agulu/Nanka erosion site, training tour guards (35.71%) at Ogbunike caves, funding (37.50%) at Nekede zoo, further development (48.15%) at Urashi river source, constructing good road (40.00%) at Oferekpe waterfall and use of modern method in salt making (48.89%) at Okposi salt lake.

CONCLUSION

There are various operations going on in different ecotourism destinations in South Eastern Nigeria which include nature of tourist reception and environmental education strategies used by the management. Some of these ecotourism operations like poor reception at Oferekpe waterfall need to be corrected. The best education strategies like the use of trained tour guards need to be adopted so that there will be someone to explain facts about the sites. Good working facilities will enhance proper functioning of the sites and attract more tourists. More trees should be planted in Agulu/Nanka erosion site to reduce the intensity of the erosion. Tourist complaints like collection of sand from the already existing erosion and hunting at Ogbunike caves should stop. Though each community has a way and reasons for protecting their destination, they have peculiar challenges that were associated to their sites. Some of these challenges was bad weather at Agulu/Nanka erosion site, slow development at Ogbunike caves, lack of funds at Nekede zoo, lack of development at Urashi river source, bad road at Oferekpe waterfall and crude method of salt production at Okposi salt lake. Provision of adequate infrastructure, access roads, further development of the sites and proper publicity will make the destinations more popular and beneficial to the inhabitants of south eastern Nigeria and Nigeria as a whole.

REFERENCES

Adetola, B.O. (2015). Ecotourism Impacts on Support Zone Communities Around Cross River National Park, Nigeria. *Journal of Sustainable Development in Africa.* 17-25.

Alabi, A. A. (2001). The Role of the Nigerian tourism development cooperation in the development of tourism in Nigeria. In Aremu, D. A. (ed), Cultural and eco-tourism development in Nigeria: the role of the threetiers of government and the private sector. Ibadan: *Hope Publications journal.* 6(2): 84-91

Brıassoulis, H. (2002). Sustainable Tourism and the Question of the Commons. *Analysis of Tourism Research* 29(4):1065-1085.

Christie, I., Fernandes, E., Messerli, H., and Twining Ward, L. (2014). Tourism in Africa: Harnessing tourism for growth and improved livelihoods. Washington, DC: World Bank

Diamantis, D. (2010). The Concept of Ecotourism: Evolution and Trends. Current Issues in Tourism. *Society and Natural Resources Journal* 2(1): 93-122.

Ekechukwu, L. C. (2006). Tourism marketing in Nigeria. In Okpoko P. U. (ed), Issues in tourism planning and development. Nsukka: *Afro-Orbis Publishing Company Ltd*. 508-520.

Fennell, D. A. (1999). Ecotourism: An Introduction. Routledge, London, 1999. 43. ISBN 0-415-14237- 7.

Guerra, J. P., Pinto, M. M., and Beato, C. (2015). Virtual reality-shows a new vision for tourism and heritage. *European Scientific Journal*, ESJ, 11(9), 49-54.

Hana, M.A and Iwona, J. (2016). The Quality of life of the Residents of Tourist Reception areas According to Selected Indicators. *Kazimierz Wielki University Journal*. 174-185

Idumah, F. O., Onyeanusi, A. E., Akinyem, O. D. and Bello, M. A. (2009). Prospects and challenges of ecotourism development in Nigeria. *Journal of Environmental Extension*. 8(1) 50 -58.

Ijeomah, H.M., Dagba, B.I. and Aju, P.C. 2007. Local Conservation Practices and Perception ofUrashi Waterfall Ecotourism Development Project, in Dikenafai Community, Imo State. *Journal of Research in Tourism*, 1:125-141

Ijeomah, H. M., Alarape, A. A., and Ogogo, A. U. (2007) Management Ethics and Strategies Towards Sustainable Tourism Development in Jos Wildlife Park, Nigeria. *Journal of Environmental Extension* – 6:72-80

Ijeomah, H.M. (2012). Impact of tourism on livelihood of communities adjoining eco destinations in Plateau state, Nigeria. *Journal of culture (Revista de Cultura e turismo), 6(3)55-71*

Ijeomah H.M. and Okoli C.I.C. (2016). Challenges of Ecotourism in Selected Destinations of Nigeria. *International Journal of Agriculture and Rural Development*. 19(2): 2655-2668.

International Union for Conservation of Nature (IUCN) (1980): World Conservation Strategy: Living Resources Conservation For Sustainable Development, Gland, Switzerland

International Union for Conservation of Nature (2002). IUCN Report on Ecotourism and Conservation. Retrieved from http://www.iucnredlist.org

Kusler, J.A. (1991). Ecotourism and resource conservation: Introduction to issues. In J.A. Kusler (compiler) Ecotourism and Resource Conservation. A Collection of Papers (1: 2–8).

Nchor, A.A., and Asuk, S.A. (2018). Potentials of community based ecotourism in IkoEsai Community of Cross River State, South-Eastern Nigeria. *International Journal of Research in Human, Arts & Literature.* 6(1):219- 226.

Nwosu, A. M. (2006). Okigwe sacred caves: human use and tourism potentials. In okpoko P. U. (ed), Issues in tourism planning and development. Nsukka: *Afro-Orbis Publishing Company Ltd.*

Ogunjinmi, A.A. (2015). Analysis of ecotourists' profiles, trip characteristics and motivations in Nigeria National Parks. *International Journal of Agriculture and Tourism* 18(1): 25-48.

Oluwakemi, A. O. and Jonathan, O. E. (2017). Ecotourism in Nigeria: The Okomu National Park Context. *Journal of Tourism, Hositality and Sports*. 28 (1) 23 – 31.

Onuchukwu P.O. and Ijeomah, H. M (2007).Impact of Tourism on Perceived Poverty Alleviation in Plateau State, Nigeria, PhD thesis. Department of Wildlife Management and Fisheries, University of Ibadan, Oyo State, Nigeria. 301pp

Okani, A. A. and Akade M.E. (2002). The Ogbunike cave: its place in the traditional religious values of Ogbunike traditionalists. An Unpublished Diploma Thesis, Department of History University of Nigeria Nsukka.

Okpoko, A. I. and Okpoko, P. U. (2002). Tourism in Nigeria. Afro-Orbis Publishers, Nsukka. 2(4). 457-466.

Sebele, L.S. (2010). Tourism ventures, benefits and challenges: Khama rhino Sanctuary trust, central district, Botswana. *Tour Manage journal*. 31(1):136- 146.

Umar A.M. (2022). Ecotourism in Nigeria, challenges and prospects: a review. *Gadau Journal of Pure and Allied Sciences 1(1): 12-17*

UNEP and WTO (2003): Sustainable tourism and poverty alleviation, world tourism organization, Mandrid, Spain, pp. 1 – 4. http://www.worldtourism.org/

Wood, M. E. (1999). The Ecotourism Society—An International NGO Committed to Sustainable Development, *Tourism Recreation Research*, 24(2): 119 – 123.

EFFECTS OF ABATTOIR EFFLUENTS ON WATER QUALITY OF NEW CALABAR RIVER, CHOBA, RIVERS STATE, NIGERIA

*Gabriel, V. I, Woke, G. N. and Komi, G. W.
Department of Animal and Environmental Biology, Faculty of Science,
University of Port Harcourt, P. M. B. 5323, Choba, Port Harcourt, Nigeria
*corresponding Authors E-mail; gentle.komi@uniport.edu.ng

Abstract

The study was to determine the concentration of effluents pollution from abattoir waste on surface water quality of New Calabar River, Choba, Rivers State, Nigeria between November 2022 and April 2023. The heavy metals tested include Ni, Fe, Cu, Zn, Pb using Atomic Absorption Spectrophotometer (A.A.S), while the physiochemical parameters include; Alkalinity, Hardness, Turbidity, Total Suspended Solid, Conductivity, pH, Temperature, Dissolved Oxygen (DO) and Biological Oxygen Demand using model 860033SPER, scientific water quality meter. The monthly and stationary mean values of dissolved Oxygen (DO) (5.82 ± 0.62^{a} and 5.61±2.17), Biological Oxygen Demand (BOD) (2.20 ± 0.29^{e} and 1.68±0.44), Total Suspended Solids (TSS) (2.88 ± 0.59^{b} and 2.63 ± 1.10^{a}), Temperature (29.10 ± 0.12^{fb} and 28.34±0.75), Hardness (49.60 ± 3.05^{b} and 45.17±18.18) and conductivity (1761.80 ± 105.86^{b} and 1365.20±662.38) respectively were within the WHO limit while Turbidity, and pH were above the threshold limit, with Turbidity recording the highest mean value of 7.93 ±1.90 Nephelometric Turbidity Unit (NTU) in December while the least mean value of 3.83±0.25 NTU in April, station 4 had the highest among the stations with a mean of 7.07±1.74 NTU, while station 2 had the least mean value of 3.75±1.54 NTU. Iron had the lowest mean of 1.623±0.654 mg/L at station 1 and highest mean value of 3.428±1.735 mg/L at station 4 all being significantly higher than the WHO limit. The other heavy metals were within acceptable limits for the different months and stations for NIS and WHO. Lead were below 0.002±0.000 mg/L and Nickel was below <0.008±0.001 mg/L in the months except November that had a mean of 0.026±0.018 mg/L but all were below the threshold. Strict adherence to regulatory standards on limits of effluents by abattoir and industries located along the river is advised.

Keywords: Abattoir effluents, Physicochemical Parameters, Heavy Metals and Water Quality

INTRODUCTION

The environment around a typical Nigerian abattoir is sometimes swampy due to insufficient wastewater channeling from slain animal dressing and lairage washings (Asibor *et al*., 2017). The majority of them are located near the surface water bodies in order to have inexpensive water supply for butchered animals processing, as well as a drain for run-off from meat processing activities (Omole and Ogbiye, 2013). Basically, abattoir activities include; butchering, hide removal, intestinal management, rendering, trimming, processing, and cleaning whereas blood, oil, mineral and organic materials, salts, and chemicals applied during handling processes are the common components of abattoir waste. Abattoir effluent has the potential to significantly increase the levels of nitrogen, phosphorus, and total solids in the receiving water body (Akange *et al*., 2016).

Water is considered an essential resource for life support and there is almost no human activity that does not involve the usage of water. The planet is covered with water, 97% of which is salty in the seas and 3% is freshwater at the poles (i.e., in the form of ice), rivers, lakes, streams, and groundwater, which serve the majority of human and animal requirements. Water can be obtained mostly from surface waterways such as streams, rivers, lakes, and lagoons (Okey-Wokeh *et al*., 2020; Al-Ghamdi *et al*., 2014). The pollution of the aquatic environment by inorganic and organic chemicals is a major factor posing serious threats to the survival of aquatic organisms (Nwankwoala, and Ngah, 2014). The pollution of water resources often results in the destruction of primary producers, which in turn leads to an immediate diminishing impact on fish yields, with the resultant consequence of decrease in diet. Pollutants are therefore chemical, physical or bacteriological in nature and can be measured more or less accurately in water, the physical and chemical characteristics of water determine the quality of water in a particular area (Ogbonna and Ideriah, 2014).

The rise in indiscriminate disposal of organic and inorganic waste in particular, the rise in abattoir activities, especially with their crude method of disposing effluents into water bodies, and the region's lack of effective environmental health monitoring and policies have all raised concerns about the ecological impacts of such activities on water bodies in terms of preserving biodiversity and ensuring that the river's economic purpose is not compromised. The Choba community abattoir, like most abattoirs in Nigeria empties its waste directly into a nearby water way, the New Calabar River. This discharge of untreated abattoir waste has the potential to have significant effects on the livelihood of individuals who rely on the water body. As a result, an updated assessment of the water quality of the impacted river is required to evaluate or determine the impact that such operations are now having on the water body. Also, to give updated statistics and data that can be utilized as a reference material for relevant authorities to carry out fast actions and monitoring to checkmate the effects of these anthropogenic activities, as well as biodiversity preservation and safety. Therefore, the aim of the study is to determine the effects of effluents pollution from abattoir on surface water quality which includes physicochemical parameters such as (Alkalinity, Hardness, Turbidity, Total Suspended Solid, Conductivity, pH, Temperature, Dissolved Oxygen and Biological Oxygen Demand) and concentration of selected Heavy Metals such as (Ni, Fe, Cu, Zn, Pb) of New Calabar River, Choba, Rivers State, Nigeria,

MATERIALS AND METHODS

Study Area

The study was conducted in Choba community of Obio Akpor local government area, which makes up Port Harcourt metropolis, Rivers State, Nigeria. Choba community is located along East West Road and lies between latitude N4° 53'30.55" and at longitude E6° 53'55.54" (Dienye and Woke, 2015).

The New Calabar River, Choba is a black water type located in Rivers State, Nigeria and lies on the Eastern aim of the Niger Delta and empties into some creeks and coastal lagoons bordering the Altantic Ocean. At the source Elele Alimini, the water is fresh and acidic but brackish and tidal at the mouth. Aluu Choba is the upstream part of the river where it is fresh and tidal. The New Calabar River, Choba is among the important water resources in the Niger Delta region of Southern Nigeria; it is in the vicinity of the rapidly expanding oil city of Port Harcourt in Rivers State, Southern Nigeria. Most communities within this area are directly dependent on the river for their agricultural, recreational and sometimes domestic water supplies. The river is subjected to effluent discharge from industries sited along its banks. Also, surface run-off resulting from soil erosion, lumbering activities, forestry operation, dredging activities and domestic sewage inputs may lead to wide scale contamination of the river (Deinye and Woke, 2015). A total of five different stations which includes; Welbros site 1, Slaughter, sedimentary, Welbros site 2 and South Africa were established as shown in Figure 1.

Sampling stations of the New Calabar River

Station 1 (Welbros site 1)

This station was sited close to the overhead bridge and is also known as Welbros site 1, there were so many human activities going on as it had so many of its badges undergoing maintenance and also dredging. There were plantain trees adjacent to it and iron fences that were only accessed by their staff only. It is located approximately at latitude N4° 53'23.22" and at longitude E6° 53'54.042"

Station 2 (Slaughter)

This station is downstream from station 1. It is located at Choba Abattoir commonly called by the people within the area as Slaughter. The water is highly polluted due to intensed anthropogenic activities, there is presence of waste disposal, fecal droppings and burning of animals and tyres in this area. There is also discharge of wastewater into the river from the abattoir. Adjacent to it is the police house boat station to fight sea pirates. There are also anchored fishing canoes and traps, as well as some fishermen fishing. It is located at Latitude N4° 53’20.49” and at longitude E6° 53’54.066”.

Station 3 (Sedimentary)

This station is known by the villagers as sedimentary, by both sides are many macrophytes but not submerged. The coloration of the water is greenish and the villagers are said to believe that some the macrophytes are medicinal. There are also traps setup by the local fishermen. This site is located at latitude N4° 53’18.738” and at longitude E6° 53’53.298”.

Station 4 (Welbros site 2)

This station is called the Welbros company site two, and opposite it is the Sydentry company with their heavily protected iron bars fences located at the bank of the river. The river coloration is greenish, with many macrophytes that are attached to the water body. There are lots of fish traps set by the local fishermen. This site also had floating waste disposals. It is located approximately at latitude N4° 53’17.13” and at longitude E6° 53’47.574”.

Station 5 (South Africa)

This station is known by the locals as South Africa, it also has an extension of the Welbros company site two. Lots of human activities were going on as there had just resumed full operations. Opposite it are human settlements, some palm trees and some macrophytes around the area. The water is highly polluted due the Welbros company activities such as; dredging, badges maintenances etc. There are heaps of dredged muds at the side of the river, with fish traps too. The water channel is wider compared to other stations and it traverses to other areas such as; Rumuolumeni, Ogbogoro etc. It is located approximately at latitude N4° 53’14.712” and at longitude E6° 53’53.154”.

Samples were collected from the established stations at the New Calabar River, Choba for six months from the month of November 2022 to the month of April 2023.

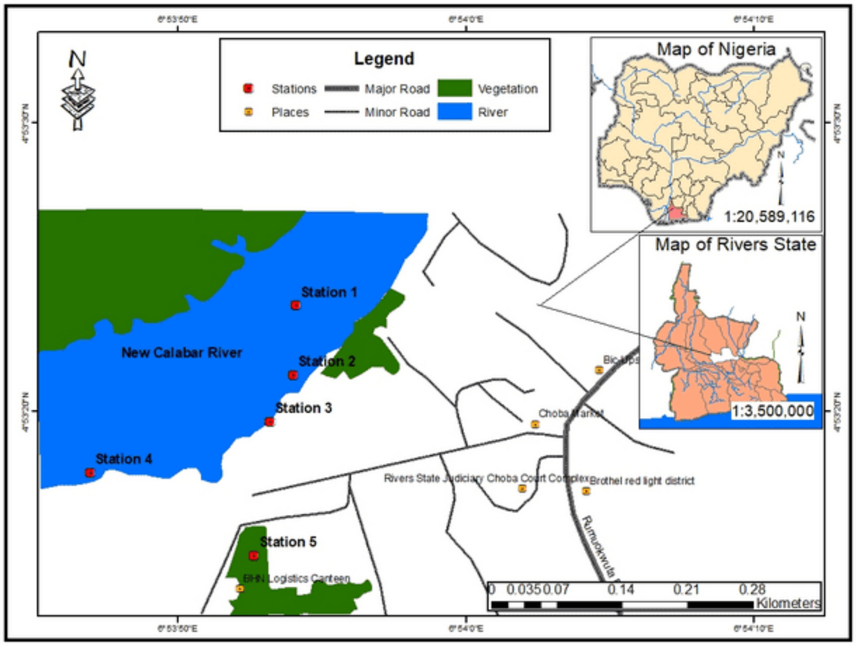


Figure 1; Map of the study area showing the different sampling stations of the New Calabar River.

Sample collection and laboratory analysis

Ten 50cl bottles were well-labeled, sterilized and used to collect surface water samples for the physicochemical parameters and heavy metals with one for each station. These water samples were taken to the Laboratory for analysis of physiochemical parameters such as; Turbidity, Alkalinity, pH, Biological Oxygen Demand (BOD), Dissolved Oxygen (DO), Hardness, Temperature, Conductivity and Total Suspended Solids (TSS). And heavy metals such as; Lead, Copper, Iron, Zinc and Nickel. The samples were received in good condition.

200ml of the water sample was measured into 250ml pyrex beaker, the probe of the water quality checker was inserted into the sample. Each of the chemical parameters was analyzed following the standard protocol using Sper scientific benchtop meter (model 860033 sper scientific water quality meter). The reading was allowed to stabilized, and the value recorded. This process was done three times and the average taken.

50ml of the sample was measured into a volumetric flask and 1ml of nitric acid was added to it. Heat was applied using heating mantle until it got to 1/3 of the 50ml volume. The sample was removed from the heating mantle and allowed to cool and was filtered into a standard flask using

Wattman (90mm) filter paper. The sample was made up to 50ml mark of the standard flask and was transferred into the 100ml plastic container. Each of the metal was measured using Atomic Absorption Spectrophotometer (A.A.S) that was calibrated daily with specific metallic standard.

Statistical Analysis

Anova was used to check for variations in physicochemical parameters and heavy metals across stations and between months. Chi-square was used to check if there were any significant variations between the stations. T-test was used to check for variations between stations and months.

RESULTS

The results of the physicochemical parameters for both monthly distribution and stationary distribution and that of the Heavy metals also for both monthly distribution and stationary distribution of the sampled sites along the New Calabar River is shown in Tables 1- 4.

Table 1: Monthly distribution of sampled Physicochemical Parameters

Parameters	November, 2022	December, 2022	January, 2023	February, 2023	March, 2023	April, 2023	NIS	WHO
Turbidity (NTU)	6.17 ± 2.15	7.93 ±1.90^{a}	5.36 ±1.91^{b}	5.30 ±1.81^{b}	5.35 ±1.45^{b}	3.83 ±0.25^{b}	5 NTU	4 NTU
Alkalinity (mg/L)	9.60 ±0.89^{a}	23.93 ±5.33^{b}	24.59 ±6.32^{b}	23.20 ±5.02^{b}	25.53 ±4.82^{b}	28.05 ±3.00^{b}		<500 mg/L
Hardness (mg/L)	14.20 ±1.79^{a}	48.80 ±14.25^{b}	40.40 ±5.37^{b}	39.20 ±3.11^{b}	41.60 ±5.59^{b}	49.60 ±3.05^{b}	150 mg/L	100 mg/L
TSS (mg/L)	0.82 ±0.26^{a}	1.46 ±0.60^{a}	1.36 ±0.38^{a}	1.78 ±0.54^{a}	2.64 ±0.70^{b}	2.88 ±0.59^{b}	500 mg/L	
Cond (µS/cm)	226.10 ±60.36^{c}	1639.40 ±125.74^{b}	1533.80 ±147.42^{b}	1582.40 ±199.19^{b}	1761.80 ±105.86^{b}	795.20 ±18.98^{a}	1000 µS/cm	2000 µS/cm
pH	9.40 ±0.05	8.64 ±0.31^{a}	8.83 ±0.04^{a}	8.83 ±0.04^{a}	8.90 ±0.03^{a}	9.64 ±0.99^{b}	6.5 – 8.0	6.5 – 8.0
Temperature °C	28.60 ±0.10^{a}	29.00 ±0.17^{b}	27.78 ±0.07^{c}	27.63 ±0.02^{c}	27.63 ±0.02^{ed}	29.10 ±0.12^{fb}	Ambient	Ambient
DO (mg/L)	5.82 ±0.62^{a}	5.74 ±0.24^{a}	4.33 ±0.21	4.33 ±0.21	3.88 ±0.05^{b}	5.14 ±3.09		5.0-7.0
BOD (mg/L)	1.68 ±0.31^{a}	1.78 ±0.15^{a}	1.34 ±0.24^{c}	1.30 ±0.20^{d}	2.20 ±0.29^{e}	0.98 ±0.18^{f}		4

Note: Different superscript is indicative of a statistically significant difference (p-value <0.05) between the means across months for each parameter while similar superscripts indicate an insignificant statistical difference (p-value >0.05). The mean values without superscripts indicates a non-statistical significant difference.

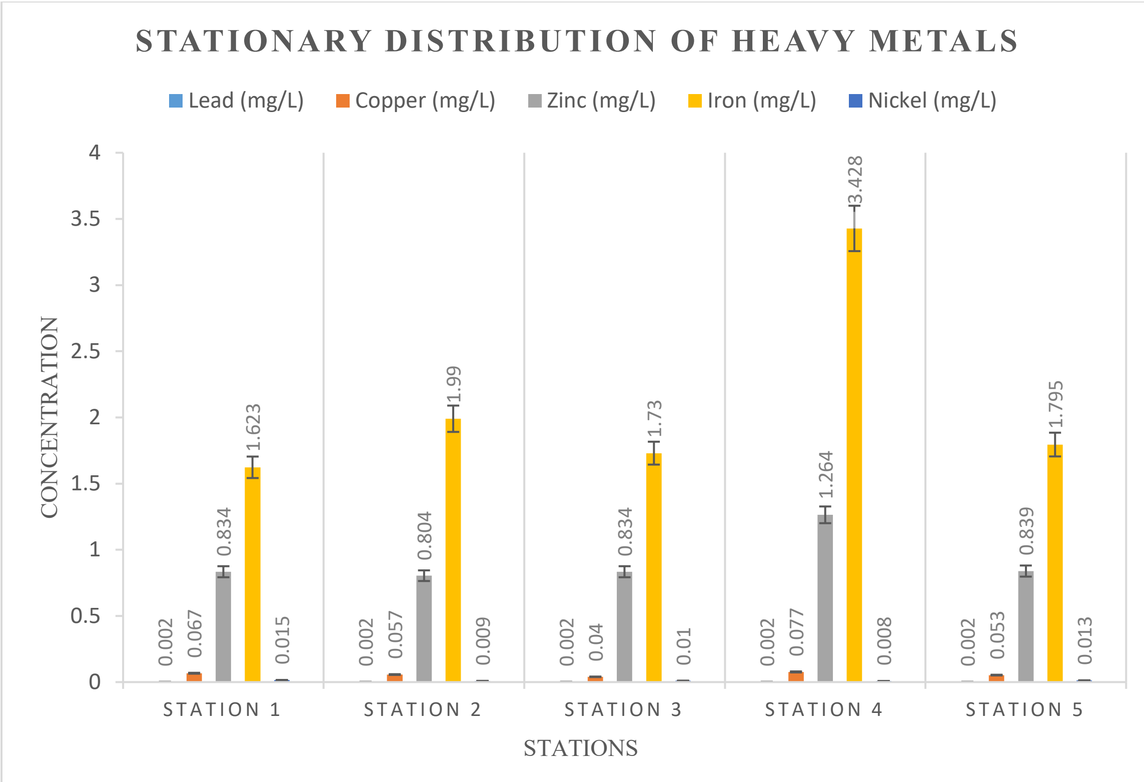
Values are displayed as Mean±SD, NIS= Nigerian Industrial Standard for drinking water quality
WHO= World Health Organisation (2017) Guidelines for drinking water quality: the fourth edition incorporating the first addendum

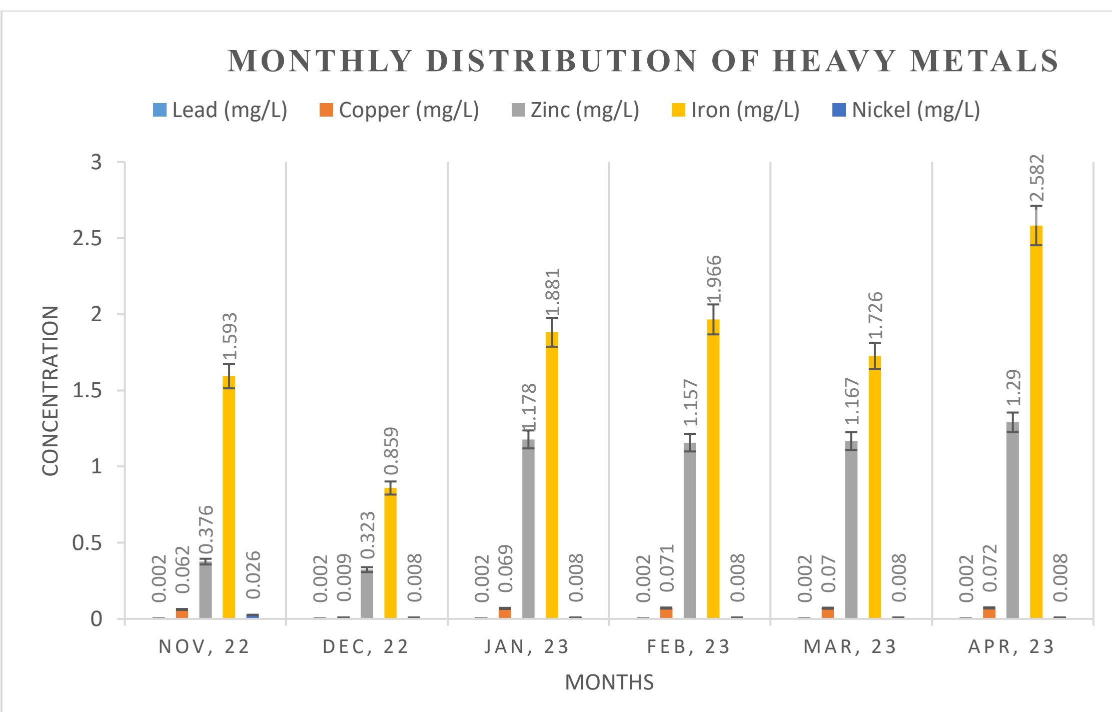
Table 2: Stationary distribution of sampled Physicochemical Parameters

Parameters	Station 1	Station 2	Station 3	Station 4	Station 5	NI
Turbidity (NTU)	5.93±1.52^{b}	3.75±1.54^{a}	5.38±2.43	7.07±±1.74^{b}	6.15±1.45^{b}	
Alkalinity (mg/L)	20.44±5.53	24.66±7.31	28.30±9.06^{a}	18.96±6.58^{b}	20.07±5.66	
Hardness (mg/L)	36.50±10.46	43.33±15.62	45.17±18.18	35.33±12.19	34.50±10.58	1
TSS (mg/L)	2.63±1.10^{a}	1.73±0.81	1.57±0.77^{b}	1.62±0.66^{b}	1.57±0.76^{b}	5
Cond (μS/cm)	1291.42±619.15	1281.42±656.73	1365.20±662.38	1153.28±566.59	1190.93±569.88	10
pH	9.23±0.56	9.31±0.87	8.97±0.31	8.86±0.34	8.84±0.33	6
Temperature °C	28.26±0.74	28.34±0.75	28.28±0.65	28.32±0.72	28.25±0.63	A
DO (mg/L)	4.79±0.79	5.61±2.17	4.44±1.30	4.47±1.46	5.05±1.04	
BOD (mg/L)	1.53±0.31	1.47±0.47	1.62±0.61	1.43±0.50	1.68±0.44	

Note: Different superscript is indicative of a statistically significant difference (p-value <0.05) between the means across months for each parameter while similar superscripts indicate an insignificant statistical difference (p-value >0.05). The mean values without superscripts indicates a non-statistical significant difference.

Values are displayed as Mean±SD
NIS= Nigerian Industrial Standard for drinking water quality
WHO= World Health Organisation (2017) Guidelines for drinking water quality: the fourth edition incorporating the first addendum


STATIONARY DISTRIBUTION OF HEAVY METALS
Lead (mg/L)
Copper (mg/L)
Zinc (mg/L)
Iron (mg/L)
Nickel (mg/L)
CONCENTRATION
STATIONS
STATION 1
STATION 2
STATION 3
STATION 4
STATION 5
0.002
0.067
0.834
1.623
0.015
0.002
0.057
0.804
1.99
0.009
0.002
0.04
0.834
1.73
0.01
0.002
0.077
1.264
3.428
0.008
0.002
0.053
0.839
1.795
0.013


MONTHLY DISTRIBUTION OF HEAVY METALS
Lead (mg/L)
Copper (mg/L)
Zinc (mg/L)
Iron (mg/L)
Nickel (mg/L)
CONCENTRATION
MONTHS
NOV, 22
DEC, 22
JAN, 23
FEB, 23
MAR, 23
APR, 23
0.002
0.062
0.376
1.593
0.026
0.002
0.009
0.323
0.859
0.008
0.002
0.069
1.178
1.881
0.008
0.002
0.071
1.157
1.966
0.008
0.002
0.07
1.167
1.726
0.008
0.002
0.072
1.29
2.582
0.008

DISCUSSION

The results for Turbidity as recorded in table 4.1 indicates that for the months of November, December, January, February and March, the turbidity was all above WHO recommended standard for turbidity for water body (WHO, 2017). The month of November and December had the highest recorded values for Turbidity (6.17 NTU, and 7.93 NTU), this increase in turbidity could lead to an overall decrease in light penetration into the water body which could negatively affect the aquatic ecosystem; as photosynthetic organisms which are the bedrock of aquatic ecosystem depends on light for their food production and upon an increase in turbidity, the amount of useable light that could penetrate into deeper regions of the water body will be reduced significantly. . When we look at the record for turbidity for the different sampling stations, it was observed that Station 4 had the highest with a mean of 7.07 NTU while station 2 had the least with a mean value of 3.75 NTU. Station 2 which is observed to have discharge from human waste and abattoir waste water had a considerably lower level of turbidity when compared with a recent publication by Nwochigoziri *et al*. (2023) who reported a turbidity with a mean value of 4.14±0.54 NTU at Choba segment of the New Calabar river. However, both were below the WHO standard. According to Alcantara *et al*, (2010) turbidity can be said to be a measure of water clarity which is caused by suspended and dissolved organic and inorganic matter in the water body. It is believed that turbidity is a major factor in the decline of aquatic organism's diversity in the aquatic ecosystems, as it diminishes light absorption and oxygen levels, thereby altering the food webs and causing population declines in such habitats. As the study progressed to the month of January and February, a significant decrease in the level of turbidity was recorded which although is higher than the recommended WHO limit of 4 NTU but it was within the recommended limit for NIS of 5 NTU (WHO, 2017; NIS, 2017). This level of turbidity could be attributed to a decrease in the rainy season with reduced in the amount of inflow or runoff coming from neighboring streams into the water body, as this level was reported to have stabilized to a level in the months of January, February and March with approximately 5.3 NTU at the recorded values. In the month of April, there was a significant decrease in turbidity with a value of 3.83 NTU compared to the earlier months of November and December, this decrease like in the previous months of March and February could be due to a decrease in rainy season which could have increased the amount of photosynthetic light available for organisms or increased the amount of sunlight available for aquatic organisms to photosynthesize and produce.

For Alkalinity, it was recorded that all the different months all had values that were below the WHO standards of <500 mg/L (WHO, 2017). However, the least recorded value of alkalinity was observed in the month of November with a mean value of 9.60 mg/L, the highest was recorded in the month of April with a value of 28.05 mg/L and this could be attributed to higher carbon dioxide concentrations and the release of bicarbonates ions by sediments during the rainy season (Igbokwe *et al*, 2021). The samples station with the least mean value for alkalinity was station 4 with a mean of 18.96 mg/L while the highest was recorded in Station 3 with a mean value of 28.30 mg/L, likewise, the stations all had an alkalinity that was at an acceptable level according to WHO (WHO, 2017). Nwochigoziri *et al*., (2023) who carried out a related study on New Calabar river reported low mean value of 14.84±1.75 mg/L which is lower than the results observed in this study for all the station points. Alkalinity has no direct effects on fishes or prawns, however due to its indirect impacts, it is can be considered a significant parameter due to its role in protecting aquatic organisms from significant variations in pH, as byproducts of aquatic organisms and microorganisms' metabolism and respiration notably phytoplankton and bacteria can alter pH levels. Water bodies with an alkalinity of above 20mg/l traps carbon dioxide (CO_2) and raises the concentration available for photosynthesis, if its presence in water is also less than 20mg/l there may not be enough carbon dioxide (CO_2) or dissolved carbonates for photosynthesis to occur thereby limiting phytoplankton growth and development. Alkalinity in aquatic environments, can be regulated by bicarbonate ions of $NaHCO_3$ and when maintained above 100mg/l, it can be an efficient buffer depending on the levels of carbon dioxide (CO_2) present in the water body. Also, since alkalinity is a source of carbon for nitrifying bacteria during nitrification, a drop below 80mg/l is not recommended, on the other hand, an excessive high level of alkalinity in an aquatic ecosystem can limit its ability to support life (Chris, 2010).

For Hardness, the recorded values for the months of November through to April were all below the acceptable standards for NIS and WHO (150 mg/L and 100 mg/L) respectively (NIS, 2017; WHO, 2017). The month of November recorded the lowest mean value of 14.20 mg/L for hardness while the month of April recorded the highest value 49.60 mg/L. Across the different sampling stations, Station 3 had the highest value with a mean value of 45.17 mg/L while the station with the least value is Station 5 with a mean value of 34.5 mg/L. Hardness of water is caused from the contamination of dissolved calcium and magnesium, and also by a variety of other minerals in water bodies (USGS, 2018). From our results, the low hardness recorded across the months and on the different sampling stations when compared with the recommended standards set by WHO and NIS is an indicator that the water body to certain extent is free from calcium salt or magnesium salt contamination during this period under study. It could also be as a result of brief rainfall seen in these months as associated with rain patterns in dry season which limited the amount of run-off from nearby lands. Since the month of April had the highest value for Hardness, it could an indicator of the presence of high magnesium content and calcium salts in the water bodies which could have been gotten from point sources especially when we look at station 2 and 3 which had higher value for the stations, as these stations had more anthropogenic activities with discharge from waste water and possible entry points from run-off from building materials such as cements used for construction.

For Total suspended Solids (TSS), the results as reported in both tables indicates that the recorded values for November, December, January, February, March and April were all below the acceptable NIS standards of 500 mg/L for Total suspended Solids (TSS) (NIS, 2017). The month of November had the lowest value of 0.82 ±0.26 mg/L whereas the month of April recorded the highest value of 2.88 ±0.59 mg/L. The station with the highest TSS was observed to be Station 1 followed by Station 2 with a mean value of 2.63±1.10 mg/L and 1.73±0.81 mg/L respectively, this station is marked by a lot of human activities especially station 2 which has an Abattoir, in addition to the presence of waste disposal and fecal droppings. The results were all lower than that reported by Nwochigoziri *et al*., (2023) who recorded a mean value of 18.10±1.55 mg/L for choba region of the River. When compared to an older study carried out by Tekenah *et al*., (2014), the results were also lower as they reported a value of 160 mg/L for the TSS. Total suspended solids determination is important in the examination of sewage and other waste fluids such as abattoir effluents. The decrease in the levels of total suspended solids as recorded in the month of November could be associated with the effect of the dry season and was probably due to sedimentation that occurred due to reduced current velocity and water level. The increase recorded in April could be due to the influx of allochthonous materials into the river by surface run-of, large quantity of silt and debris held in suspension just before the rains (Olawale, 2016).

From the results recorded for Conductivity, it was observed that that result from the month of November and April were below the acceptable standards for NIS and WHO respectively whereas, December all through to the month of March were all above the acceptable standards of 1000 µS/cm for the NIS; however, they were below the acceptable standards of 2000 µS/cm for WHO

(NIS, 2017; WHO, 2017). The month of November recorded the lowest value of 226.10 ±60.36 µS/cm whereas, the month of March recorded the highest value of 1761.80 ±105.86 µS/cm. Station 3 had the highest mean conductivity with a value of 1365.20±662.38 µS/cm, while station 4 had the lowest mean value of 1153.28±566.59 µS/cm. this region is marked by activities such as fishing as local fishermen setup their traps within this region. The result for the different stations in this study were all above the report of Edori and Nna (2018), who recorded a value of 812.69±22.35 µS/cm for Choba section of the river. The decreased conductivity levels recorded during the wet seasons maybe attributed to water dilution, decrease in the concentration of salts, organic and inorganic substances in the water body which could have emanated from runoff from domestic and other anthropogenic sources whereas, the increased levels of conductivity recorded during the dry seasons might have been due to the reduction of water volume and high rates of evaporation. Conductivity relatively shows the presence of inorganic pollution and it is a measure of total dissolved solids and ionized species present in the water body as a result of indiscriminate dumping of abattoir effluents and sewages. (Igbokwe *et al*., 2021; Olawale, 2016).

The overall results for pH as observed in the different months was higher than the recommended limits set by WHO and NIS (WHO, 2017; NIS, 2017). It was observed that the month of November and the month of April both had overall higher levels of pH with a mean value of 9.40 ±0.05 and 9.64 ±0.99 respectively while the lowest was recorded in the months of January and February with a mean value of 8.83 ±0.04 however, all was still higher than the recommended limits of 6.5 – 8.0 for WHO and NIS. Stations 1 and 2 both had a high pH mean value of 9.23±0.56 and 9.31±0.87 respectively. Station 2 which is marked with discharge of abattoir waste and other waste water discharge had the highest pH among the different stations. These values were all higher than the report of Nwochigoziri *et al*., (2023) who recorded a value of 6.88±0.33 in their study, when also compared with the report of Tekenah *et al*., (2014), the results were also higher for all the stations as they recorded a value of 7.42, 7.14 and 7.0 for the upstream, midstream and downstream section of the Choba region of New Calabar River. High pH values indicate an increase in the overall alkalinity of the water body and this increase of pH in the water body has been suggested to be as a result of the discharge of abattoir effluents into the water body, as they tend to be alkaline in nature due to a result of high concentrations of organic compounds that are present composed mainly of protein (Mulu *et al*., 2013).

The results for the temperature indicate a significant increase in the early months of November and December before decreasing in the months of January through to the month of March during the dry seasons. The month of April had an increase in the average temperature which is towards the onset of the wet season. However, the record for the different stations showed that the temperature across the statin was relatively constant, as the mean value all revolved around 28 ^oC. This average temperature for the different stations is approximately the same as reported by Nwochigoziri *et al*., (2023) in their study. Indicating that those anthropogenic activities that occurs along the river region has little impact on the temperature changes of the river, although the month variations suggests that seasonal changes does indeed have an effect as we can see by the significant increase and decrease of the temperature for the different months as we move from December to April. This data also agrees with the results of physicochemical analysis that was carried out by Tekenah *et al*., (2014) on the same river.

The monthly variation in the mean value for dissolved oxygen can be seen to follow an interesting pattern of having a higher value during the wet season months before the onset of the dry season with a mean value of 5.82 ±0.62 mg/L and 5.74 ±0.24 mg/L for the months of November and December respectively. This value reduced during the dry season months of January all through to the month of March and increase in the month of April, a 2013 to 2014 study on same river by Dienye and Woke (2015) observed similar pattern with a decrease in the mean value of DO in the months of February and March, with an increase in the month of April. However, this pattern is not in agreement with the study of Nwochigoziri *et al*., (2023), who reported a higher mean value of DO during the dry season and a lower DO during the wet season. Tekenah *et al*., (2014) in their study, also reported a lower mean value of DO at 4.40 mg/L at the region exposed to abattoir discharge during the wet season which was lower than the results obtained for the station 2 that recorded a mean value of 5.61±2.17 mg/L which was the highest for all the stations sampled. The level of DO is considered as one of the most crucial water quality parameters due to aquatic life that is dependent on the amount of oxygen present in the water to be utilized by aquatic biota. Many information can be revealed by looking at the concentration of dissolved oxygen in water such as the level of bacterial activity, photosynthesis, nutrients availability, stratification and survival of fishes (Premlata, 2019; Edori and Nna 2018). The WHO recommended limit for DO is a range of 5.0-7.0 mg/L, and when we look at the results we obtained, the months of January to March had the lower mean value for DO which were below the WHO limit; in addition, station 1, 3 and 4 were also lower than the WHO recommended limit. Algal blooms are known to create anoxic conditions which lowers the DO levels in the water; this occurs because excessive algae growth due to increase in nutrients such as nitrogen and phosphorus. Upon excessive growth, the algae will also decompose, this decomposition process demands oxygen, therefore the level of DO that is available for fish and other aquatic organisms will greatly decreased, which will impact fish health, typically killing them (CORIS, 2012).

The results for the BOD were observed to be not significantly different between the months of November and December, but reduced significantly in the dry months of January and February. It was also observed that it increased significantly in the month of March and decreased again in the month of April. The mean valued of the BOD for the different months were all observed to be higher than the report of Dienye and Woke (2015) in their publication for the New Calabar River in 2014. The results obtained in this study were all below the WHO standard of 4 mg/L, even when we look at the results for the different stations, they were not higher than the WHO limit. It is important to note that a high level of BOD indicates that more oxygen is required, which implies that there is less oxygen for oxygen-demanding species to feed on, and consequently signifies lower water quality. Inversely, a lower record of BOD means less oxygen is being removed from water, so the water is generally purer. Therefore, BOD in river water will increase if sewage, decayed organic matter, nutrient load and/or dead macrophytes which are released into the river by human activities or through surface water runoff gets mixed up with the river water as they utilize oxygen for their biodegradation. But, from our results, the BOD for the different stations was observed to be lower than the WHO standard which implies that the organic pollution is not high ((Ngah et al., 2017; Nwochigoziri et al.,2023).

The results for lead which is a very harmful heavy metal to both humans and aquatic life was recorded to be below 0.002±.000 mg/L for the different months under consideration and also for the different stations that was sampled. This result is a good indicator that there is no lead contamination in the river and as such, human activities such as fishing can be encouraged. A former study in same section of the river published in 2017 recorded a mean concentration of 1.03 mg/L (Nwankwoala and Angaya 2017), when compared to the present result, we can see a significant reduction in the level of lead contamination. Lead is a known harmful environmental pollutant that has high toxic effects on numerous human organs. It can be absorbed through the skin, although it is primarily absorbed through the digestive and respiratory systems. Due to pathways which includes; immunological regulation, oxidative stress and inflammation, exposures to lead may cause inflammatory reactions in many organs and upset the equilibrium of the oxidant-antioxidant systems. Its exposure has a number of disorders related with it and changes how the body functions physiologically. Due to its high toxicity, the body's neurological, biochemical and cognitive capabilities are negatively impacted, and the concern about lead at the global level blood poisoning is defined as 10g/dl. Opium adulteration with lead has been viewed as a threat to human health in recent years (Kianoush *et al.*, 2012; Kianoush *et al*., 2015).

The concentration of copper from the results all indicate that there is no copper contamination as they mean value for copper concentration for the different months were also all below the set standard by WHO and NIS for copper level, when we look at the stations too, the level of copper concentration for the different stations although higher in station 4 compared to other stations does not constitute any ecological or health concerns. A 2019 study on choba section of New Calabar river revealed a high copper concentration of 2.363 mg/L which was higher than the set limit by both NIS and WHO of 1.0 mg/L and 2.0 mg/L respectively (NIS, 2017; WHO, 2017; Nwineewii *et al*., 2019), this recent study when compared to the report of Nwineewii *et al*., (2019), shows a significant reduction in the level of copper contamination. The concentrations copper (Cu^{2+}) is usually low naturally in coastal areas and water bodies, but due to the increase in industrialization and other anthropogenic activities, increment disposal of refuse in water bodies and industrial discharge into the water without treatment results in an increase in the copper concentrations (Leal *et al*., 2016).

The Zinc concentration recorded for the different months in the study were not above the WHO and NIS recommended limit as the highest mean value was 1.178±0.234 mg/L which was recorded in the month of January, the limit of 5.0 mg/L and 3.0 mg/L was not exceeded (WHO, 2017; NIS, 2017). When we look at the concentration at the different sampling station, the station with the highest concentration of Zinc was station 4 with a mean value of 1.264±0.610 mg/L. This station is marked by the presence of Welbros company site two and Sydentry company. A 2017 reported by Nwankwoala and Angaya (2017) recorded a mean value of 1.35 mg/L and compared to the results from this study, the value can be said to have not increased but reduced albeit slightly. The concentrations of zinc in water can increase due to industrial sources or toxic waste sites, which might result in negative health effects (Gautam *et al*, 2016). Zinc is present in high concentrations in the wastewater from industrial operations, which causes water pollution, therefore, rivers that are frequently exposed to Zinc contaminated waste-water will result in deposits of Zinc-polluted sludge on their banks leading to the water becoming more acidic as a result of zinc (Ross *et al*., 2023).

Unlike the results of other heavy metals in this study, the level of Iron in the river were all higher than both the NIS limit and the WHO limit for the different months. The month of April had the highest mean value for Iron concentration with a mean of 2.582±0.348 mg/L and when compared to the NIS and WHO limit of 0.3 mg/L and 0.05-0.3 mg/L respectively, we can say that the water is polluted (WHO, 2017; NIS, 2017). This is an indicator that the month of April had the highest level of pollution as this value is significantly higher than the recommended limit. When we look at the stations, the station with the highest mean value for Iron concentration was station 4 with a mean value of 3.428±1.735 mg/L. This station has Welbros company site two and Sydentry company located around it and also has sightings of waste disposal. Solid wastes have been known to contribute to pollution and can be hazardous to human health. Leachate generated from within the waste heap are known sources of both inorganic and organic hazardous substances which can undergo migration with the flow of storm water to contaminate both surface and groundwater (Leton, 2013; Nwankwoala *et al*., 2017). The other stations samples all had higher level of Iron concentration that are beyond the NIS and WHO limit, all indicating possible pollution. The river is subjected to effluent discharge from industries which are located along its banks, and among the different environmental pollutants; heavy metals are of particular concern because of their potential toxic effect and ability to undergo bio-accumulation in aquatic ecosystem (Censi *et al*., 2006; Akankali *et al*., 2022).

The level of Nickel in the different months were all below detectable limits with all being less than 0.008±.001 mg/L except the month of November with a value of 0.026±0.018 mg/L which was slightly higher than the set limit of 0.01 mg/L by NIS but below the limit of 0.07 mg/L set by WHO (WHO, 2017). The stations all had a mean concentration of nickel that was within the limit of NIS and WHO. Nickel has a wide range of carcinogenic mechanisms, including the regulation of transcription factors, the controlled expression of specific genes, and the creation of free radicals. Nickel has been linked to the regulation of specific lengthy non-coding ribonucleic acids (RNA). It has also been established that nickel can form free radicals, which adds to carcinogenic processes. (Guo *et al*., 2019).

CONCLUSION

Based on the results from the study, aside turbidity and pH which had higher values beyond the recommended limit as recorded in November 2022 and April 2023 and in all the stations, the results of other physicochemical parameters were all within the Nigerian Industrial Standard (NIS) and World Health Organization (WHO) standards. However, there were monthly variations in the record of the different parameters indicating the effect of the wet and dry season in the physicochemical parameters. The station affected by anthropogenic activities such as the abattoir and waste disposal also contributed to the recorded variation. In the heavy metal assessment, the different metals tested were all within the acceptable limits of the WHO with lead and nickel being lower than detectable limits; the exception was iron which was significantly higher than the WHO limit. This is of environmental concern as it indicates that there is an incident of heavy metal pollution. Therefore, it become important that the agencies responsible for maintenance of river quality take proactive steps in the development and implementation of strategies that will improve the current state of the New Calabar River.

REFERENCES

Akange, E.T., Chaha, J.A. and Odo, J.I. (2016). Impact of Wurukum abattoir effluent on river Benue Nigeria, using macroinvertebrates as bioindicators. *International Journal of Aquaculture* 6(22):1–11. https://doi.org/10.5376/ija.2016.06.0022

Akankali, J. A, Davies I. C. and Tambari-Tebere A. (2022). Pollution Impacts of Abattoir and Associated Activities Wastes on the Water Quality of Eagle Island Creek, Niger Delta, *Nigeria International Journal of Contemporary Applied Researches* Vol. 9, No. (2), 2308-1365

Alcantara, E., Novo, E., Stech, J., Lorenzzetti, J., Barbosa, C., Assireu, A. and Souza, A. (2010). A contribution to understanding the turbidity behavior in an Amazon floodplain. *Hydrology and Earth System Science*. 14(2), 351-364

Al-Ghamdi, A.Y., Mohamed, E.I.S. Al-Ghamdi, A.O., and Zabin, S.A. (2014). Study of Physicochemical Properties of the Surface and Ground Water. *American Journal of Environmental Science 10 (3):* 219 – 235

Asibor, G., Edjere, O. and Ofejiro, P. (2017). Physico-chemical and bacteriological assessment of abattoir effluents and its effects on Agbarho River, Delta State Nigeria. *Nigerian Journal of Applied Science*, 35, pp. 265–276.

Censi P, Spoto SE, Saiano F, Sprovieri M, Mazzola S, Nardone G (2006). Heavy metals in coastal waste systems. A case study from the Northwestern gulf of Thailand. *Journal of Asian Earth Sciences; 6(4)*:1167-1176

CoRIS (2012). An assessment of chemical contaminants detected in passive water samplers deployed in St. Thomas east end reserves (STEER) https://repository.library.noaa.gov/view/noaa/779

Dienye, H.E. and Woke, G.N. (2015). Physicochemical Parameters of the Upper and Lower Reach of the New Calabar River Niger Delta. *Journal of Fisheries & Livestock Production.3(4):* 1000154

Edori, O.S. and Nna, P.J. (2018). Determination of Physicochemical Parameters of Effluents at Discharge Points into the New Calabar River along Rumuolumeni Axis, Port Harcourt, Rivers State, Niger Delta, Nigeria. *Journal of Environmental & Analytical Toxicology, 08(05).* doi:10.4172/2161-0525.1000585

Gautam, P. K., Gautam, R. K., Banerjee, S., Chattopadhyaya, M. C. and Pandey, J. D. (2016). Heavy metals in the environment: fate, transport, toxicity and remediation technologies. Nova Sci Publishers, 60, 101-130.

Guo, H., Liu, H., Wu, H. Cui, H., Fang, J., Zuo,Z., Deng, J., Li, Y, Wang, X and Zhao, L (2019). Nickel Carcinogenesis Mechanism: DNA Damage. International Journal of Molecular Science 20(19). 4690; https://doi.org/10.3390/ijms20194690

Igbokwe, S.O, Ogueri, C. and Ajima, M.N.O. (2021). Seasonal variation in physicochemical characteristics of Agulu Lake, South Eastern Nigeria. *International Journal of Fisheries and Aquatic Studies 9(2)*: 91-97.

Kianoush S. Balali-Mood M.,Mousavi S.R. Moradi V., Sadeghi M., Dadpour B. (2012).Comparison of therapeutic effects of garlic and d-penicillamine in patient with chronic occupational Lead poisoning. *Basic Clinical Pharmacology and Toxicology* 110(5), 476-481

Kianoush S., Sadeghi M. and Balali-Mood M. (2015). Recent advances in the clinical management of lead poisoning. *Acta Medical Iran* 53,327-336

Leal, P.P., Hurd, C.L., Sander, S.G., Armstrong, E. and Roleda, M.Y. (2016) copper excotoxicology of marine algae: a methodological appraisal, *Chemistry and Ecology*. Doi:10.1080/02757540.2016.1177520

Leton, T.G. (2013). Engineering with a Human Face.University of Port Harcourt lnaugural Lecture Series No. l0l.Delivered 28s. February, 2013. ISSN: 11l9-984902013.

Mulu, A., Ayenew, T. and Berhe, S. (2013). Impact of Slaughterhouses Effluent onWater Quality of Modjo and Akaki Rivers in Central Ethiopia. *International Journal of Science and Research*, 4(3):899 - 907

Ngah, A; Braide, S; Dike, C (2017). Physico-chemistry of Elechi creek in the upper Bonny estuary, Rivers State, Nigeria. *Journal of Geosciences and Environmental Protection, 5:* 181-197.

Nwankwoala H. O and Angaya Y. B. (2017). An Evaluation of Heavy Metals Concentration in the Choba Section of the New Calabar River, Eastern Niger Delta. *Scientific Review* 3(6):54 - 61

Nwankwoala, H.O and Ngah, S.A (2014). Groundwater resources of the Niger Delta: quality implications and management considerations. *International Journal of Water Resources and Environmental Engineering 6(5)* https://academicjoumals.org/joumal/IJWREE/article-full-textpdf/5FE7BD944836>. (Accesed 4 January, 2022)

Nwankwoala, H.O.; Angaya, Y.B.; Amadi, A.N. and Amehr I.M (2017). Contamination Risk Assessment of Physico-chemical and Heavy Metal Distribution in Water and Sediments of the Choba Section of the New Calabar River, Nigeria. *Nigeria Journal of Engineering and Applied Sciences* 4(1):15-24

Nwineewii J. D., Edori O. S. and Marcus A. C. (2019). Heavy metal content of surface water and crab (*Potamon fluviatile*) from the New Calabar River, Rivers State, Nigeria. *Journal of Chemical Society of Nigeria, 44(*6):1035 -1043

Nwochigoziri, E. C; Ekpete, O. A; Kpee, F. (2023). Assessment of Physicochemical Parameters of New Calabar and Orashi Rivers Exposed to Open Waste Discharge in Nigeria. *Journal of Applied Science and Environmental Management 27 (7):* 1541-1549

Ogbonna, D.N. and Ideriah, T.J.K. (2014). Effect of Abattoir Waste Water on physic-chemical characteristics of soil and sediment in southern, *Nigeria Journal of Scientific Research and Reports* 3(12): 1612-1632.

Okey-Wokeh, C.G., Obunwo, C.C., and Boisa, N. (2020). Assessment of Physicochemical Characteristics of Mini-Ezi Stream in Elele-Alimini, Emohua Local Government Area of Rivers State, Nigeria. *International Journal of Advancement in Science and Research Engineering, 6 (1*): 1 – 8

Olawale, S. A. (2016). Physicochemical Analysis of Water from Asa River, Ilorin, Nigeria. *Imperial journal of interdisciplinary research.* 2: 1362-2454

Omole, D. O. and Ogbiye, A. S. (2013). An Evaluation of Slaughterhouse Wastes in South-West Nigeria. *American Journal of Environmental Protection*. 2 (3): 85-89.

Premlata, V. (2019) Multivariant analysis of drinking water quality parameters of Lake Pichhola in Udaipur, India. *Biological Forum-An International Journal 1:* 97-102.

Ross, M. M., Hernandez-Espinosa, D. R. and Aizenman, E. (2023). Neurodevelopmental Consequences of Dietary Zinc Deficiency: A Status Report. *Biological Trace Element Research,* 1-24 pp.

Tekenah, W.E., Agi, P.I. and Babatunde, B.B. (2014). Analysis of surface water pollution from abattoirs and the interrelationship between physicochemical properties. (A case study of the New Calabar River). *Journal of Environmental Science Toxicology and Food Technology,* 8(5): 10-18

U.S. Geological Survey,(2018). Mineral Commodity Summaries 2018: U.S. Geological Survey, 200 p. https://doi.org/10.3133/70194932.

WHO (World Health Organisation) (2017). Children: reducing mortality. http://www.who.int/newsroom/fact-sheets/detai l/children-reducingmortality.

Carbon Footprint from Chemical Industry and its Impact on Economic Development in Nigeria

Aigbedion Edward
Alwell Nteegah
Obindah Gershon
Emerald Energy Institute
University of Port Harcourt
Corresponding Author: Edward Aigbedion
eddybim99@gmail.com

ABSTRACT

To generate electricity, Nigeria heavily relies on heavy fossil fuels. In 2018, Nigeria was estimated to have CO2 emissions per capita of 0.57 metric tons. This number has been going up over the past three years, going from 0.44 metric tons in 2016 to 0.56 metric tons in 2017, an increase of 29%. The apparent dearth of data on the connection between the chemical industry's efforts to reduce its carbon footprint and Nigeria's economic development is the root of the problem. Using data series spanning 1990–2019, this study set out to establish a connection between the chemical industry's efforts to reduce its carbon impact and economic growth in Nigeria. The effect of reducing the chemical industry's carbon footprint on Nigeria's economic development was the primary research question. The research looked at the connections between reducing the chemical industry's carbon footprint and economic development using a quantitative method using the ordinary least squares linear multiple regression technique. The regression results show that the three independent variables are statistically significant at the 5% level, with a p-value for CO_2 emissions from the chemical industrial sectors being less than 0.05 (5%). The findings showed that economic development will drop by 0.0038 units for every unit rise in CO_2 emissions from the chemical industry. Reducing the chemical industry's carbon footprint is one of the study's recommended measures.

Keywords: Global Warming, Carbon Footprint, Human Development Index

1.0 Introduction

A growing number of people are worried about the effects of climate change (Yurtsever & Firat, 2019). The production of energy in Nigeria is heavily reliant on the use of fossil fuels. One of the biggest worries for human existence is the rise in global temperatures, which is caused by fossil fuels. According to Zoom (2018). The government of Nigeria has made tremendous efforts to limit rising greenhouse gas emissions to an absolute minimum by the year 2030, and it is a party to the Paris Climate Agreement. But these consequences haven't solved the problem for good. In 2018, Nigeria was estimated to have CO_2 emissions per capita of 0.57 metric tons. This number has been going up over the past three years, going from 0.44 metric tons in 2016 to 0.56 metric tons in 2017, an increase of 29%. In 2019, the World Data Atlas reported... The issue at hand is the apparent dearth of data concerning the connection between lowering carbon footprints and boosting Nigeria's economy (Efe, 2016).

One study looked at the correlation between energy use, carbon emissions, and GDP growth in China (2018), while another looked at the same thing in Nigeria (2015), specifically at the correlation between energy use, carbon dioxide (CO_2) emissions, and GDP. Research by Zou, Chindo et al., and others has not examined the connection between emissions and monetary growth. I want to address this knowledge vacuum by studying the relationship between Nigeria's carbon footprint and economic development via the lens of the Human Development Index (HDI), a surrogate for economic development.

Using time series data from 1990 to 2019, this quantitative analysis set out to establish the connection between lowering carbon footprints and economic progress in Nigeria. Advancement in the economy was the dependent variable in this research. Industrial and power sector CO_2 emissions served as the independent variables. The purpose of the research was to establish a connection between CO_2 emissions from various sources and economic growth in Nigeria.

2.0 Literature review

The acceleration of CO_2 emissions is a factor in the global warming phenomenon. (Change et al., 2006; Inglesi-Lotz & Dogan, 2018). Not only does fossil fuel have negative effects, but it is also not sustainable, as it is easily depleted and expensive to produce and maintain (Day & Day, 2017; Li et al., 2017). Wind, water, solar, and geothermal power are all examples of renewable energy (RE) sources. These power sources are both naturally occurring and regenerative.

According to Ellabban et al. (2014), renewable energy technology is the foundation of the energy supply of the future. Using Panel Smooth Transition Regression (PSTR) model data from 1980-2008, Heidari et al. (2015) examined the relationship between economic growth, CO_2 emissions, and energy consumption in five Southeast Asian nations. The feasibility of reducing emissions from public transport in the US was investigated by Ercan et al. (2016). In their 2017 study, Aye and Edoja used a dynamic panel threshold framework to look at the impact of CO_2 emissions in 31 developing nations. Friedrichs and Inderwildi (2013) attempted to assess fuel-rich nations with high CO_2 intensities via the lens of the carbon curse theory. Using a dynamic panel threshold approach, researchers Frondel et al. (2010) and Aye and Edoja (2017) examined the impact of CO_2 emissions in 31 developing nations.

Using panel VAR spanning 1971–2011, Antonakakis et al. (2017) investigated the interplay between real GDP per capita growth, CO_2 emissions per capita growth, and energy consumption per capita growth. The sample size was 106 nations. In their search for efficient carbon reduction strategies, Kucukvar et al. (2015) used a worldwide, scope-based carbon footprint model. The findings revealed that among the supply chains of Turkish industrial sectors, the one with the greatest carbon footprint was the one dealing with energy, gas, and water. In order to suggest efficient policies for reducing carbon emissions, Kucukvar et al. (2015) modelled carbon footprints using the Turkish experience. From an Indian perspective, Luthra et al. (2015) provided an explanation for the obstacles to the widespread use of renewable and sustainable energy sources. Reduce the carbon footprint of locally integrated energy sectors by integrating waste and renewable energy, according to Perry et al. (2008). The motivations behind reducing one's carbon footprint were investigated by Schwenkenbecher (2014). Using data from three North African countries from 1980 to 2012, Kais and Ben-Mbarek (2017) looked at the correlation between CO_2 emissions, energy usage, and GDP growth. In Bangladesh, Arfanuzzaman (2016) looked at how EPI was affected by CO_2 emissions, per capita income, and HDI. Erdoğan (2019) used a fully modified OLS technique to search for a correlation between CO_2 emissions and economic growth in the BRICS-T nations. The results show that carbon emissions and economic growth are related in both directions.

So far, researchers have looked at how energy use, carbon emissions, and GDP growth are related. Energy consumption, carbon emissions, and economic growth were the subjects of a study by Zou (2018). Energy usage, CO_2 emissions, and GDP were the subjects of research by Chindo et al. (2015) in Nigeria. The relationship between carbon footprint and economic development in Nigeria was not examined in any of the studies cited by Zou, Chindo et al. This study aims to fill that void by studying the relationship between Nigeria's carbon footprint and its economic development, with the HDI serving as a surrogate for economic development. There needs to be a balance between Nigeria's socioeconomic well-being and its carbon footprint, and this report will start a national discussion about that.

2.1 **Conceptual literature**

2.1.1 Concept of Carbon Footprint

The ecological footprint, which estimates human impact on earth's ecosystems, inspired the carbon footprint. It is a standardized indicator of natural capital demand that may differ from the planet's ecological regeneration capability. It is the ecologically productive land and marine area needed to feed humans and absorb their waste. (Gao et al., 2014). Country carbon footprint is the amount of carbon dioxide released into the atmosphere by humans. Annual **CO_2** emissions are quantified in equivalent tons of carbon dioxide. (Aichele & Felbermayr, 2012); Change et al. Modern society faces a major challenge: climate change. International and local authorities want a tool to monitor climate change's impact, which is measured by greenhouse gas emissions. Carbon footprint was used to measure greenhouse gas emissions easily**.**

2.1.2 Sources of CO2 Emission

CO_2 emissions are human-caused. Mancini et al. (2016) categorized CO_2 emissions from anthropogenic activities into three sources, based on the International Energy Agency: fossil fuel combustion, non-fossil fuel sources like forest fires, gas flaring, cement production, and unsustainable biofuel production, and marine and aviation transport. Mancini et al. reported that the three sources contributed 78%, 19%, and 3% of 2010 emissions. Contrary to Mancini et al., Fenner et al. (2018) believe the built environment accounts for most of society's carbon emissions. Fenner et al. sought a simple, consistent, and easy carbon emission assessment method for buildings. Hussain et al. (2012) found that energy consumption per capita in Pakistan is the main cause of environmental pollution.

3.0 METHODOLOGY

3.1 Research Design and Rationale

This study was guided by the overarching research question: what is the impact of carbon footprint reduction from chemical industry on economic development in Nigeria?. The variables for this study include CO_2 emission from chemical industry (OSC). The dependent variable was economic development (ED), proxied human development index (HDI).

3.1.1 Model Specification

To specify the model, I defaulted to the original traditional production theory model as follows:

$$Y = f(L, K, etc.) \quad (3.1)$$

where output is a function of labour (L) and capital (K). Introducing energy consumption and CO2 into the model, we have the following model:

$$Y = f(L, K, ECON) \quad (3.2)$$

where output is a function of labour (L), capital (K), and energy consumption (ECON).

Also, CO2 emissions, which is a by-product, can be modeled as follows:

$$CO2 = h(f(L, K, ECON)) \quad (3.3)$$

$$HDI = f(CO2) \quad (3.4)$$

Substituting the function, the value of CO2 in eq 3.18

$$HDI = F(L, K, ECON) \quad (3.5)$$

Replacing energy consumption with total CO2 emission and distilling CO2 emission into major sources, namely transport, other sectors, and building. keeping K and L constant,

we have:

HDI = f (OSC) (3.6)

Linearizing the above model and expressing it in explicit form, we have

$$HDI = \beta_0 + \beta_1 OSC_t + \varepsilon_t \quad (3.7)$$

Where:

β_0 = constant

$\beta_{1,}$ = coefficients.

ε_t = Error term.

HDI = Human Development Index (a proxy for economic development)

OSC = CO_2 emission from other sector

4.0 Results

4.1 Sources of Data

The focus of the study was the Nigerian economy. Only secondary data was used in this study. The study's scope was time-series data from 1990 to 2019 which was used to estimate the regression model. The data required included CO_2 generated from other sectors (OSC), and human development Index (HDI). These data were sourced from the Global greenhouse gas and CO_2 emission and United Nations Development Program UNDP.

4.2 Variable Selection

The dependent variable chosen for the analysis was the economic development proxied by human development Index (HDI). The independent variable was fossil fuel from other sectors (OSC). Table 1 below illustrates the variables summary.

Table 4.1

Variables Summary

Name	Variable	Description	Form
HDI	Dependent	Economic Development	linear
OSC	Independent	CO_2 generated from Fossil fuel	linear

Source: Author's compilation.

Table 4.2

Augmented Dickey-fuller Unit Root Test Results- Case: Constant

Variable	Level-None	1st Diff- None	Decision
OSC	-1.0322 (0.2648)	-6.1990 (0.0000)	Non-stationary at Level; Stationary at 1st difference

Variable	Level-Constant	1st Diff-Constant	Decision
HDI	0.4078 (0.9798)	-4.5360 (0.0012)	Non-stationary at Level; Stationary at 1st difference
OSC	-0.7329 (0.8228)	-6.2610 (0.0000)	Non-stationary at Level; Stationary at 1st difference

Note. values in parenthesis are t-statistics while values in bracket are p-values

Table 4.3

Augmented Dickey-fuller Unit Root Test Results- Case: Constant & Trend

Variable	Level-Constant & Trend	1st Diff-Constant & Trend	Decision
OSC	-2.7949 (0.2102)	-6.2368 (0.0001)	Non-stationary at Level; Stationary at 1st difference

Note. values in parenthesis are t-statistics while values in bracket are p-values.

The null hypothesis of a unit root cannot be rejected for any variable in the level form (Pesaran et al., 1996). Conversely, all variables exhibit unit roots. However, the null hypothesis of a unit root is rejected for variables only when first differenced. The unit root test using the Augmented Dickey-Fuller is found in Table 2-4

Table 4.4

Cointegration Test Result

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.764277	93.90579	88.80380	0.0203
At most 1	0.517162	53.44306	63.87610	0.2746
At most 2	0.445121	33.05697	42.91525	0.3336

At most 3	0.315774	16.56485	25.87211	0.4481
At most 4	0.191145	5.939782	12.51798	0.4680

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.764277	40.46273	38.33101	0.0280
At most 1	0.517162	20.38609	32.11832	0.6214
At most 2	0.445121	16.49212	25.82321	0.5013
At most 3	0.315774	10.62506	19.38704	0.5524
At most 4	0.191145	5.939782	12.51798	0.4680

There are two tables to check while interpreting the result of the cointegration test. The trace statistic and Max- Eugen statistics. When the trace statistics is greater than the critical value at 5% level of significance and the p-value is less than 0.05 we reject the Null hypothesis of no cointegration. The other way is to check the Max- Eugen statistics: if the Max-Eugen statistics is greater than the critical value and p-value is less than 0.05 (5% level of significance).

4.3 Model Estimation

The output of the regression model is shown in Table 6 below.

Table 4.5

Regression Output (Dependent Variable: HDI

Variable	Coefficient	Std. Error	t-Statistic	Prob.

OSC	-0.003851	0.000793	-4.855261	*0.0001
C	0.424637	0.027649	15.35793	0.0000

R-squared	0.882482	Mean dependent var	0.477867
Adjusted R-squared	0.863679	S.D. dependent var	0.032800
F-statistic	46.93340	Durbin-Watson stat	1.035203
Prob(F-statistic)	0.000000		

From the value of R-squared being 0.8825, this indicates that the model is 88.25 % fit; this implies that the regression model is a very good fit because the independent variables cumulatively explain 88.25 % of the dependent variable. The combined f-statistic is significant because the p-value is less than 0.05 (5%), which means that the independent variables jointly can influence the dependent variable HDI.

Table 4.6 below shows the long-run equation between the independent and dependent variables.

Table 4.6

Long run Regression Equation Estimation -VECM

	Coefficient	Std. Error	t-Statistic	Prob.
C(1) =HDI	-1.107443	0.275505	-4.019686	0.0006
C(2)= D(HDI)	0.227281	0.163450	1.390525	0.1789
C(3)= OSC	0.000513	0.000625	0.820383	0.4212
C(4)=C	0.002708	0.001141	2.373196	0.0273

R-squared	0.619871	Mean dependent var	0.003714

Adjusted R-squared	0.511263	S.D. dependent var	0.006188
S.E. of regression	0.004326	Akaike info criterion	-7.836169
Sum squared resid	0.000393	Schwarz criterion	-7.503118
F-statistic	5.707399	Durbin-Watson stat	1.965450
Prob(F-statistic)	0.001193		

From Table 4.6 above, the coefficient C1 is the speed of adjustment towards a long-run equilibrium but must be significant and should be negative.

4.1.8 Short-Run Relationship Between Variables.

Results of Wald Test for Short-Run Relationship

Table 4.7

Independent Variable	Coefficient	Chi-Square Prob	F- Stat Prob	Decision
OSC and HDI	C(3)	0.4120	0.4212	No short-run relationship

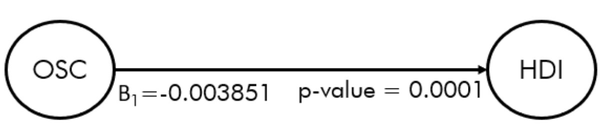
4.4 Data Analysis

4.4.1 Model Estimation

From the value of R-squared being 0.8825, this indicates that the model is 88.25 % fit, this implies that the regression model is a very good fit because the independent variable cumulatively explains 88.25 % of the dependent variable. The f-statistics is significance because the p-value is less than 0.05 (5%), it means that the independent variables jointly can influence the dependent variable HDI. For the individual independent variables, if the p-values are less than 0.05 (5%), then the respective variable is significance, that is the independent variables determines the dependent variable HDI in a good way, however if the p-values is greater that 0.05(5%) it meant the variable in question is not significant. From the regression output in Table 4.5, CO2 emission from other sector (OSC) have a p-values less than 0.05 (5%) which indicates that these three independent variables are significant at 5% level. Conversely CO_2 emission from buildings have p-values greater than 5 % level, and therefore not significant.

Further analysis of the study revealed that CO_2 emission from other sector (OSC) has a negative effect on economic development with a coefficient of -0.003851, which meant that if the emission from other sector increases by one-unit economic development will reduce by 0.003851. The last indicator is the Durbin- Watson stat, this value is used to ascertain if the model is spurious. If the Durbin-Watson stat is less than R-squared then it is an indication of a spurious model. From the regression output, the Durbin-Watson value is 1.03 and the R-squared value is 0.8825, which infer that the model is not spurious. In the final analysis the regression model is a good fit because R-squared has a high value, the F-stat is significant, same goes for three of the independent variables. Beside the value of R-squared is less than Durbin-Watson stat indicating that the model is fit. Figure 4.1 below depicts the pictorial representation of the variables (HDI, TCO2, BLDC, TRPT, and OSC). It shows the p-values and the respective value for the coefficient (β_1, β_2, β_3, and β_4).

Figure 4.1
Heuristic Model



NB. β refers to coefficients,
Source: (Researcher's Study Outcome, 2021).

5.1 Conclusion

5.2 CO_2 Emission from Chemical Sector and Economic Development

There is a statistically significant relationship between CO2 emission from chemical industry and economic development in Nigeria from the study. We can conclude that an increase in CO_2 emissions from chemical sectors will reduce economic development.

5.2 Recommendations

This section highlights the recommendations for policy and future research. This study will help address the preponderance of greenhouse gasses. It will stimulate a national discussion on the need to balance carbon footprint and Nigeria's socio-economic wellbeing. Knowledge gained from the study will provide Nigeria's government with sufficient information on how to reduce carbon footprint in the country.

5.2.1 Recommendation for Policy

The policy recommendations that could be gleaned from the study are

Reduce the emission of CO2 from chemical industry combustion, the following measure are encouraged:

(i) Nigeria should come out with the ambition to be carbon neutral in all their processes.

(ii)The reforestation program of the government should be strengthened.

References

Aichele, R., & Felbermayr, G. (2012). Kyoto and the carbon footprint of nations. *Journal of Environmental Economics and Management*, *63*(3), 336-354.

https://doi.org/10.1016/j.jeem.2011.10.005

Antonakakis, N., Chatziantoniou, I., & Filis, G. (2017). Energy consumption, CO2 emissions, and economic growth: An ethical dilemma. *Renewable and Sustainable Energy Reviews, 68*, 808–824. https://doi.org/10.1016/j.rser.2016.09.105

Arfanuzzaman, M. (2016). Impact of CO2 emission, per capita income and HDI on Environmental Performance Index: empirical evidence from Bangladesh. *International Journal of Green Economics*, *10*(3-4), 213-225. https://doi.org/10.1504/IJGE.2016.081900

Aye, G. C., & Edoja, P. E. (2017). Effect of economic growth on CO2 emission in developing countries: Evidence from a dynamic panel threshold model. *Cogent Economics & Finance*, *5*(1), 1379239. https://doi.org/10.1080/23322039.2017.1379239

Change, A. D. C., Blair, T., & Pachauri, R. (2006). *Avoiding dangerous climate change*. Cambridge University Press.

Chel, A., & Kaushik, G. (2018). Renewable energy technologies for sustainable development of energy-efficient building. Alexandria Engineering Journal, 57(2), 655-669. https://doi.org/10.1016/j.aej.2017.02.027

Chindo, S., Abdulrahim, A., Waziri, S. I., Huong, W. M., & Ahmad, A. A. (2015). Energy consumption, CO 2 emissions and GDP in Nigeria. *GeoJournal*, *80*(3), 315-322. https://doi.org/10.1007/s10708-014-9558-6

Day, C., & Day, G. (2017). Climate change, fossil fuel prices and depletion: The rationale for a falling export tax. *Economic Modelling*, *63*, 153-160.

Efe, S. I. (2016). Evaluation of carbon dioxide emissions and temperature variation in Nigerian cities. *Journal of Geography, Environment and Earth Science International*, *6*(2), 1-9. https://doi.org/10.9734/JGEESI/2016/25669

Ellabban, O., Abu-Rub, H., & Blaabjerg, F. (2014). Renewable energy resources: Current status, prospects, and enabling technology. *Renewable and Sustainable Energy Reviews*, *39*, 748-764.Retrieved from: https://doi.org/10.1016/j.rser.2014.07.113

Ercan, T., Onat, N. C., & Tatari, O. (2016). Investigating carbon footprint reduction potential of public transportation in the United States: A system dynamics approach. *Journal of cleaner production*, *133*, 1260-1276. https://doi.org/10.1016/j.jclepro.2016.06.051

Friedrichs, J., & Inderwildi, O. R. (2013). The carbon curse: Are fuel-rich countries doomed to high CO2 intensities? *Energy Policy*, *62*, 1356-1365. http://dx.doi.org/10.1016/j.enpol.2013.07.076

Frondel, M., Ritter, N., Schmidt, C. M., & Vance, C. (2010). Economic impacts from the promotion of renewable energy technologies: The German experience. *Energy Policy*, *38*(8), 4048-4056.

Gao, T., Liu, Q., & Wang, J. (2014). A comparative study of carbon footprint and assessment standards. *International Journal of Low-Carbon Technologies*, *9*(3), 237-243. https://doi.org/10.1093/ijlct/ctt041.

Heidari, H., Turan Katircioğlu, S., & Saeidpour, L. (2015). Economic growth, CO2 emissions, and energy consumption in the five ASEAN countries. International Journal of Electrical Power & Energy Systems, 64, 785–791. https://doi.org/10.1016/j.ijepes.2014.07.081

Hussain, M., Javaid, M. I., & Drake, P. R. (2012). An econometric study of carbon dioxide (CO2) emissions, energy consumption, and economic growth of Pakistan. *International Journal of Energy Sector Management*. http://doi.org/10.1108/17506221211282019

Inglesi-Lotz, R., & Dogan, E. (2018). The role of renewable versus non-renewable energy to the level of CO2 emissions a panel analysis of sub-Saharan Africa's Big 10 electricity generators. *Renewable Energy*, *123*, 36-43. https://doi.org/10.1016/j.renene.2018.02.041

Kucukvar, M., Egilmez, G., Onat, N. C., & Samadi, H. (2015). A global, scope-based carbon footprint modelling for effective carbon reduction policies: Lessons from Turkish manufacturing. *Sustainable Production and Consumption*, *1*, 47-66.

Li, N., Zhang, X., Shi, M., & Zhou, S. (2017). The prospects of China's long-term economic development and CO2 emissions under fossil fuel supply constraints. *Resources, Conservation and Recycling*, 1(*121)*, 11-22. https://doi.org/10.1016/j.resconrec.2016.03.016

Luthra, S., Kumar, S., Garg, D., & Haleem, A. (2015). Barriers to renewable/sustainable energy technologies adoption: an Indian perspective. *Renewable and sustainable energy reviews*, *41*, 762-776. https://doi.org/10.1016/j.rser.2014.08.077

Mancini, M. S., Galli, A., Niccolucci, V., Lin, D., Bastianoni, S., Wackernagel, M., & Marchettini, N. (2016). Ecological footprint: refining the carbon footprint calculation. *Ecological indicators*, 1(*61)*, 390-403. https://doi.org/10.1016/j.ecolind.2015.09.040

Perry, S., Klemeš, J., & Bulatov, I. (2008). Integrating waste and renewable energy to reduce the carbon footprint of locally integrated energy sectors. *Energy*, *33*(10), 1489-1497. https://doi.org/10.1016/j.energy.2008.03.008

Pesaran, M. H., Shin, Y., & Smith, R. J. (1996). *Testing for the 'Existence of a Long-run Relationship'* (No. 9622). Faculty of Economics, University of Cambridge.

Schwenkenbecher, A. (2014). Is there an obligation to reduce one's carbon footprint? *A critical review of international social and political philosophy*, *17*(2), 168-188.

World Data Atlas. (2019). Nigeria - CO2 emissions per capita. Retrieved from: https://knoema.com/atlas/Nigeria

Zou, X. (2018). VECM Model Analysis of Carbon Emissions, GDP, and International Crude Oil Prices. *Discrete Dynamics in Nature and Society*, *2018*. https://doi.org/10.1155/2018/5350308

Yurtsever, Ö., & Firat, S. U. (2019). An Evaluation on Carbon Footprint Indicators in Turkey Located Banks and Worldwide Banks. *International Journal of Business Analytics (IJBAN)*, *6*(4), 74-95. https://doi.org/10.4018/IJBAN.2019100106

ARABLE CROP FARMERS CLIMATE CHANGE INFORMATION ACCESSIBILITY IN SOUTH-SOUTH NIGERIA

***[1]Aroyehun, A.R., [1]Onoja, A.O. and [1]Ugwuja, V.C.**

[1] University of Port Harcourt, Agricultural Economics and Agribusiness Management Department

***Corresponding Author: richestaro2014@gmail.com**

ABSTRACT

The quality and timely access to climate change information by farmers can be a decisive factor in how farmers cope with climate changes. Hence, this research examined the arable crop farmers' climate change information accessibility in South-South Nigeria. Multistage sampling techniques were used to select 90 arable crop farmers from three States in the study area, making 270 and 260 were retrieved for analysis. Data were collected through the use of a set of questionnaire and interview schedule. Descriptive statistics and multiple linear regression models were used for the analysis. Variance Inflating Factor (VIF) values were greater than one and within the acceptable region. The Tolerance is approximately one (1) which shows that multicollinearity does not exist. Durbin-Watson is two (2); indicates zero autocorrelation. Majority (95%) has access to information on climate change, 97% were awareness of climate change, and with 74% and 66% experienced flood and drought respectively. 84.6% of farmers received information on climate change through villagers' meetings, while 74.2% and 50% via radio and television respectively. Variables that had significant influence on climate change information accessibility of the arable crop farmers were educational level ($t = 3.290$; $p = 0.001$), farmer association ($t = -2.142$; $p = 0.033$), farming experience ($t = 2.498$; $p = 0.013$), awareness of climate change ($t = 22.974$; $p = 0.000$), radio ($t = 3.171$; $p = 0.002$), and television ($t = 2.087$; $p = 0.038$). The overall regression model ANOVA ($F = 64.811$ ($0.000 < 0.05$)) is statistically significant. The research therefore, recommends that extension agents should be increased, community-based climate change information centers should be established, mobile applications and SMS services should be developed to deliver weather forecasts to farmers directly, rural infrastructures should be improved, farmers can form associations to pool resources to access climate change information.

Keywords: Accessibility, Climate change, Information.

INTRODUCTION

Climate change consequences are associated natural tragedies which has caused huge economic loses globally; in 2018 about USD 225 billion across the world was recorded as loss (Alidu, Man, Ramli, Haris and Alhassan, 2022). About 95 per cent of these losses are as a result of prevalence of windstorms, floods, fire and drought as well as increase in sea level and increase in temperature which is directly linked to climate change put stress and burden on agricultural lands (Arora, 2019; Schmidt, Gonda and Transiskus, 2021). Climate changes further possess a global dare directly affecting human beings and their socio-economic daily activities consisting of health, livelihood, income, food security and wellbeing (Adeagbo, Ojo and Adetoro, 2021). Climate change also has a destructive upshot on the livelihoods of people, agricultural production, fresh water supply and other vital natural resources that are very essential for the survival of human beings (Alidu *et al*., 2022). Over the past three decades' climate change has contributed to agricultural production reduction globally between 1-5 percent per decade (Porter *et al*., 2014 as cited in Alidu *et al*., 2022).

Threats to agricultural production arising from changes in precipitation patterns which has resulted in increasing desertification in the Sahel region and flooding in the southern part of Nigeria (Okoro, Agwu and Anugwa, 2016)**;** To efficiently acclimatize to the whims of climate change, arable crop farmers need information on climate change; to an extent deficit in information, in itself, is a kind of vulnerability as it is simple for the void to be stuffed and brimful with vague, inaccurate and misleading information. According to Okoro *et al* (2016) information needs, if efficiently met, could enable and facilitate the user (the arable crop farmer) to make accurate decisions on any related problem associated with climate change facing arable crop productivity. Although many arable crop farmers are already coping with unstable climatic conditions, the weather conditions are becoming unpredictable, and some of the farmers' strategies may likely not suitable.

Timely and appropriate information on climate change of about three to six months prior to an adaptation initiative is a prerequisite for agricultural productivity and minimizes risk associated with climate change (World Bank 2016). Climate information involves the provision of daily, weekly, seasonal, medium and long-term provisions on temperatures and rainfall patterns, as well as wind, soil moisture and ocean conditions. The Nigerian Meteorological Agency (NIMET) is the national originator of climate change information which is provided from a network of national weather station on daily, weekly, monthly, seasonal as well as decadal timescales. This is sustained by international agencies, NGOs, community-based organizations, private organizations as well as research institutions. The climate information services are communicated via different dissemination channels such as radio, television, newspapers, mobile phone apps, online, agricultural extension agents, farmers' association meetings, village meetings. However, the potential benefits can only be achieved, if the climate information services are accessible, accurate and relevant for decision makers including arable crop farmers. Limited access of climate prediction has been reported in Sub-Saharan Africa (Vermeulen *et al*., 2011). Nigeria has scanty information on access to climate information particularly, South-South Nigeria.

Various studies have assessed the state of access and use of climate information using diverse models. For instance, Alidu *et al* (2022) used bivariate probit model to access smallholder farmers access to climate information and climate smart adaptation practices in the northern region of Ghana; Aliyu, Olawepo and Muhammad (2019) used descriptive to access climate change information for farmers in Nigeria focusing on women; Okoro *et al* (2016) also used descriptive to access climate change information needs of rural farmers in Enugu State; while Imam and Babuga (2021)reviewed extensively on utilization of climate change information sources among farmers in Nigeria. However, there appear to be no clear research done focusing on arable crop farmers' access and sources of climate change information in South-South Nigeria. Therefore, this study desired to fill this knowledge gap by examining the arable crop farmers' climate change information accessibility in South-South Nigeria.

The specific objectives are to:

iv. identify the socio-economics and institutional characteristics of arable crop farmers in the study area;
v. identify the sources of climate change information of the arable crop farmers in the study area; and
vi. determine climate change information accessibility of the arable crop farmers in the study area.

Hypothesis

The null hypothesis for the study was:

Ho i: The socio-economic and institutional characteristics of arable crop farmers do not have any significant influence on farmer's access to climate change information.

MATERIAL AND METHODS

The research was carried out in South-South territory of Nigeria. The South-South territory is characterized as the terrain consists of natural delta of the Niger River and the zone to the east and west of Nigeria. The natural boundaries of the South-South region can be distinct by its topography and hydrographic nature. South-South region northern boundaries are close to the divergence of the Niger River at Aboh, and the western and eastern boundaries are near the Benin River and the Imo River, respectively. South-South region consists of six States and they are Cross River State, Edo State, Rivers State, Delta, Akwa-Ibom State, and Bayelsa State. South-South region is typically a low-lying marshy area with dense network system of twisty rivers and creeks. The climate in the South-South region also favours the growing of cash crops such as coconut, pears, cocoa, cashew, oil palm, kolanut, gum Arabic, sesame and rubber among others. Arable crop grown in the Region include rice, cassava, maize, melon, yams, cocoyam, and sweet potatoes.

Multistage sampling procedures were used in the selection of respondents. First, three (3) States were selected using simple random technique from the six South-South States that's Akwa-Ibom, Bayelsa and Rivers State. Secondly, all the agricultural zones were selected in each States, making twelve (12) agricultural zones selected. Thirdly, one (1) Local Government Area (LGA) was selected from each agricultural zone using simple random technique, making a total of twelve (12) LGAs in all. Fourthly, three (3) communities were selected from each LGAs using simple random technique making a total of nine (9) and eighteen (18) communities respectively from each State and thirty-six (36) communities in all. Lastly, from each community, with the help of the local extension personnel, a list of arable crop farming households was compiled and then ten (10) and five (5) arable crop farmers were selected respectively (based on the number of Agricultural Zones in the State) using simple random technique. This makes a total sample size of two hundred and seventy (270) arable crop farmers selected for the study. While 260 was retrieved for analysis. Descriptive and multiple linear regression model were used to analyze the data obtained using Statistical Package for the Social Sciences (SPSS 25.0) software, in addition multicollinearity of the variables were also examined.

Variance Inflating Factor (VIF) was used to test the multicollinearity in the models (GeeksforGeeks, 2021). VIF is expressed in regression model as;

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \cdots + \beta_k X_k \quad (1)$$

$$VIF = \frac{1}{1-R^2} \quad (2)$$

Where; $R^2 = \frac{\Sigma(y_{cal}-\bar{y})^2}{\Sigma(y_{given}-\bar{y})^2}$ (3)

Table1: Decision Rules for Multicollinearity

VIF value	Decision/ Conclusion
VIF = 1	Not correlated (multicollinearity does not exist).
1 < VIF ≤ 5	Moderately correlated (low-level of multicollinearity exist).
VIF > 5	Highly correlated (high-level of multicollinearity exist).

The inverse of VIF is known as Tolerance and expressed as;

$$TOL = \frac{1}{VIF} = (1 - R^2) \quad (4)$$

Therefore, when R^2 is equal to zero ($R^2 = 0$), it indicates absence of existence of collinearity, then the Tolerance is high (i.e equal to 1).

Model Specification

The multiple linear regression model for climate change information accessibility as used by Okoro *et al* (2016) in accessing climate change information needs of rural farmers is expressed as;

$$Y = \beta + \alpha_1 X_1 + \alpha_2 X_2 + \alpha_3 X_3 + \cdots + \alpha_{12} X_{12} + \mu \quad (5)$$

Where: Y = knowledge on climate change issues; β = constant term; α_1- α_{12}= regression coefficients; X_1-X_{12} = independent variables; and μ = error term.

The implicit form of the regression equation is expressed as;

$$Y = \beta_0 + \alpha_1 X_1 + \alpha_2 X_2 + \alpha_3 X_3 + \alpha_4 X_4 + \cdots + \alpha_{10} X_{10} + \mu \qquad (6)$$

Where;

Y = Access to climate change information (1 = if yes; 0 = otherwise)

X_1 = Age (number of years)

X_2 = Gender (1 = if male; 0 = female)

X_3 = Marital status (single =1; married = 2; widow/widower = 3; divorced = 4)

X_4 = Educational level (number of years spent in formal education)

X_5 = Household size (actual number of people living in the household)

X_6 = Farmers association (1 = if yes; 0 = otherwise)

X_7 = Farming experience (number of years)

X_8 = Extension contacts in the last one year (in number)

X_9 = Flooding of farmland (1 = if yes; 0 = otherwise)

X_{10} = Drought (1 = if yes; 0 = otherwise)

β_0 = Constant

α_1 - α_{10} = Coefficient of estimates

μ = Error term

RESULTS AND DISCUSSION

Collinearity diagnostics of multiple linear regression model used for arable crop farmers access to climate change information analysis

Table 2 shows the collinearity diagnostics of multiple linear regression model used for arable crop farmers access to climate change information analysis

Table 2: Collinearity Diagnostics of Multiple Linear Regression Model Used for Arable Crop Farmers Access to Climate Change Information Analysis

	Collinearity Statistics	
Variables	**Tolerance**	**VIF**
Age (in year)	0.458	2.184
Gender	0.917	1.091
Marital status	0.602	1.662
Educational level (in years)	0.784	1.276
Household size (in number)	0.862	1.161
Farmer association(s)	0.780	1.282
Farming experience (in years)	0.620	1.612
Extension contacted in the last one (1) year	0.807	1.240
Awareness of climate change	0.714	1.400
Flooding of farmlands	0.738	1.355
Drought	0.708	1.412
Radio	0.780	1.282
Television	0.890	1.123

Source: Field Survey, 2023

From Table 2 it could be concluded that multicollinearity does not exist; which indicates that the variables were not correlated. At most age (in year) of the arable crop farmers in the study area has low-level of multicollinearity exist of VIF value of 2.184; which indicates moderate correlation, since the VIF values were greater than one (1) and also within the acceptable region. Tolerance levels are approximately equal to one (1); this indicates absence of collinearity and Tolerance level is high. Therefore, the model is suitable to measure the data collected.

Descriptive analysis and summary statistics of arable crop farmers

Table 3 shows the descriptive statistics for the variables utilized in the analysis.

Table 3: Descriptive Analysis and Summary Statistics of Arable Crop Farmers

Variables	Mean	Std. Deviation
Access to information on climate change	0.95	0.211

Age (in year)	49.39	10.291
Gender	0.41	0.492
Marital status	2.07	0.516
Education level (in years)	7.84	5.239
Household size (in number)	6	1.882
Farmer association(s)	0.24	0.430
Farming experience (in years)	22.90	13.476
Extension contacted within one (1) year	0.26	0.441
Awareness of climate change	0.97	0.183
Flooding of farmlands	0.74	0.439
Drought	0.66	0.476

Source: Field Survey, 2023

From Table 3, majority (95%) of the arable crop farmers had access to information on climate change while just few (5%) had no access to the information on climate change. This implies that the arable crop farmers could have less impact of climate change in their arable crop farming and could adopt appropriate mitigation and/ or adaptation strategies to minimize the losses associated with climate change impacts. This finding agrees with Alidu *et al* (2022) who found out that 81.1% had access to climate information among smallholder farmers in northern region of Ghana. The mean age of the arable crop farmers is about 49 years and this indicates that farmers are within an active working age group for agricultural production. This finding agrees with Alidu *et al* (2022) who reported a mean age of farmers in northern region of Ghana to be 39 years. However, the finding controverts with Mueme, Mburu, Coulibaly and Mutune (2018) who found out the mean age of famers to be 53 years in Kenya showing that majority of the youth in kenya do not partake in agricultural production activities.

As shown in Table 3, 41% of the arable crop farmers are males while 59% are females. The dominance in female arable crop farmers in this research agrees with the finding of Nyang'au, Mohamed, Mango, Makate and Wangeci (2021) who found a large number of female famers in Kisii, Kenya, noted that this could be as a result of majority of the male farmers has migrated to urban centres for extra income as farm sizes shrank. However, it contradicts with that of Alidu *et al* (2022) who reported 77% males among smallholder farmers in northern region of Ghana. Table 3, also revealed that most arable crop farmers were married with mean of 2.07. The average years spent to acquired formal education is 7.8 years. This indicates that majority of arable crop farmers can read and write enough to keep farming operation records as well as increase accessibility to climate change information, which could lead to adoption of appropriate mitigation and/ or adaptation strategies and productivity of arable crops. This finding agrees with Rizwan, Ping, Saboor, Ahmed, Zhang, Deyi and Teng (2019) who found out that the years spent attain the level of education among farmers in Pakistan was 7.21 years.

As shown in Table 3, the mean household size is six (6). This shows that the arable crop farmers get more labour force to employ while aiming to increase crop productivity. This finding agrees with the report of Rizwan *et al* (2019) and Enimu, Onome, Okuma and Achoja (2022) who obtained a mean of seven (7) and eight (8) household sizes among crop farmers in Pakistan and Delta State Nigeria respectively. As regards farmers association, 24% belong to one or more farmers' association. This shows that most of the arable crop farmers in the study area did not belong to any farmer association. This finding does not agree with Alidu *et al* (2022) who reported that 86.3% of farmers in northern region of Ghana belong to farmers association. It has been established that farmers who belong to any group or an association gives them a type of social capital not only agricultural credit and inputs for farming but also provides them the opportunity to share vital information such as market and climate change Adeagbo *et al*., 2021).

As presented in Table 3, the farming experience of the arable crop farmers is 22.9 years at average. This implies that the farming experience could contribute to the accessibility of climate change information to avert climate change negative impacts. This finding agrees with Rizwan *et al* (2019) and Enimu *et al* (2022) who found out that the mean of farming experience to be about 20.34 years and 24 years in Pakistan and

Delta State Nigeria respectively. About 26% of the arable crop farmers had access or been visited by agricultural extension officers within one year. This finding is at variance with Alidu *et al* (2022) who reported 78.3% in Ghana. However, Muema *et al* (2018) opined that access to agricultural extension services by farmers is very crucial human capital that gives them information on current agricultural methods and climate change information in order to improve mitigation and/ or adaptation strategies.

The result from Table 3 indicates that majority (97%) of the arable crop farmers were aware of climate change scenario. This means that arable crop farmers in the study area were to a large extent aware of climate change. This finding agrees with Sow, Bah, Sow and Yaffa (2018) who reported about 64.7% of farmers in Kaffrine Region of Senegal that were aware of climate change. As result 74% and 66% of the arable crop farmers in the study area experienced flood and drought respectively.

Source of Information on Climate Change

The sources of information on climate change by the arable crop farmers is presented in Table 4

Table 4: Source of Information on Climate Change

Variables	Frequency*	Percentage
Radio	193	74.2
Television	130	50.0
Social groups/association	21	8.1
Fellow farmers	163	62.7
Extension workers	52	20.0
NGOs	18	6.9
Internet/Social media	47	18.1
Phone (App, Google etc)	48	18.5
Villager’s meeting	220	84.6
Printed materials	16	6.2

Note: * means multiple responses

Source: Field Survey, 2023.

From Table 4, majority (84.6%) of the arable crop farmers received information on climate change through villagers' meetings. This finding agrees with Okoro *et al* (2016) who found out 83.8% of farmers in Enugu State Nigeria received climate change information from friends. Furthermore, 74.2% received information on climate change via radio. This finding agrees with Okoro *et al* (2016) who reported 57.1% of farmers in Enugu State Nigeria received information on climate change through radio. About 50% of the arable crop farmers received information on climate change through television. Similarly, 62.7% of the arable crop farmers received information on climate change from fellow farmers. This high percentage in receiving information through villagers meeting could be as a result of inadequate power supply or outright of power to those communities. However, information from radio and television were more authentic way of relating the information to the arable crop farmers, since radio and television stations relay agricultural programmes to the people. Information from social group/association, fellow farmers, phone, internet/ social media as well as from villagers meeting are not to be trusted or depend on with efficient information as this because they may not be coming from a proving and tested sources which could pose a risk to production.

Climate change information accessibility of the arable crop farmers

Accessibility of information on climate change by the arable crop farmers is presented in Table 5

Table 5: Climate change information accessibility of the arable crop farmers

	Unstandardized Coefficients		Standardized Coefficients		
Variables	**B**	**Std. Error**	**Beta**	**t**	**Sig.**
Constant	-0.098	0.056		-1.743	0.083
Age (in year)	0.001	0.001	-0.019	-0.413	0.680
Gender	0.008	0.014	0.019	0.600	0.549
Marital status	0.021	0.016	0.051	1.297	0.196
Educational level (in years)	0.005	0.001	0.113	3.290	0.001*

Household size (in number)	0.001	0.004	0.004	0.117	0.907
Farmer association(s)	-0.036	0.017	-0.074	-2.142	0.033*
Farming experience (in years)	0.002	0.001	0.096	2.498	0.013*
Extension contact within a year	0.009	0.016	0.020	0.587	0.558
Awareness of climate change	0.946	0.041	0.824	22.974	0.000*
Flooding of farmlands	-0.014	0.017	-0.030	-0.846	0.398
Drought	0.003	0.016	0.007	0.196	0.845
Radio	0.053	0.017	0.109	3.171	0.002*
Television	0.028	0.014	0.067	2.087	0.038*

Note: Model summary: R = 0.880; R^2 = 0.775; Adjusted R^2 = 0.763; Standard error of the estimate = 0.103; Durbin-Watson = 2; $p \leq 0.05$; * indicates significant at 5%.
Source: Field Survey, 2023.

Results of the multiple linear regression analysis on influence of socio-economic and institutional characteristics on climate change information accessibility of the arable crop farmers is presented in Table 5. The overall regression model shows that R which is the square root of R^2 indicates 88% correlation between the observed and predicted values of dependent variable. R^2 of 0.775 was obtained; this value indicates that 77.5% of the variance in climate change information accessibility of the arable crop farmers can be predicted from the independent variables, while adjusted R^2 accounted for 76.3% of the variance. The standard error of the estimate (0.103) indicates better fitness of the regression model to the data. The Durbin-Watson statistic is a test for autocorrelation in a regression model's output, Durbin-Watson of approximately two (2) was obtained; indicates zero autocorrelation. This Durbin-Watson result agrees with VIF and Tolerance in Table 2 establish absence multicollinearity. Standardized coefficients actually compare the variables to see which had the strongest relationship with the dependent variable, range from 0 to 1 or 0 to -1 (depend on the direction of the relationship), awareness of climate change (0.824) had the strongest relationship with access to climate change information among arable crop farmers in South-South Nigeria.

Educational level measured in number of years spent to acquire formal education (t = 3.290; p = 0.001) with coefficient of 0.005 is positively statistically significant influencing climate change information accessibility of the arable crop farmers. This implies that arable crop farmers with higher number of years in formal education could have more access to climate change information. This finding agrees with Okoro *et al* (2016) who found out that formal educational level had a significant positive influence on knowledge level of agriculture related climate change issues among farmers in Enugu State Nigeria. The higher the level of formal education, the more a farmer is likely to have access to climate change information (Tologbonse, Auta, Bidoli, Jaliya, Onu and Issa, 2010). Farmer association (t = -2.142; p = 0.033) with coefficient of -0.036 is negatively statistically significant influencing climate change information accessibility of the arable crop farmers. This negative coefficient could be as a result of most of the arable crop farmers did not belong to any farmer association in the study area, as seen in Table 3 only 24% of the arable crop farmers belong to farmers association. Hence, they could not partake in exchanging of ideas among the members on climate change information. This finding is at variance with Okoro *et al* (2016) who obtained a positive coefficient and indicated that most farmers belong to one or more farmer's association or social groups where they exchanged ideas among the members on climate change issues.

Farming experience (t = 2.498; p = 0.013) with coefficient of 0.002 is positively statistically significant influencing climate change information accessibility of the arable crop farmers. This implies that majority of arable crop farmers were aware of climate change which could increase the rate of climate change information accessibility. While awareness of climate change (t = 22.974; p = 0.000) with coefficient of 0.946 is positively statistically significant influencing climate change information accessibility of the arable crop farmers. This finding agree with Imam and Babuga (2021) who noted that high rate of climate change awareness is more evident with farmers with over 40 years of farming experience.

Radio ($t = 3.171$; $p = 0.002$) with coefficient of 0.053 is positively statistically significant influencing climate change information accessibility of the arable crop farmers. Television ($t = 2.087$; $p = 0.038$) with coefficient of 0.028 is positively statistically significant influencing climate change information accessibility of the arable crop farmers. This implies that access to radio and television by the arable crop farmers increases climate change information accessibility.

Analysis Of Variance (ANOVA) of Socio-economic and Institutional Characteristics of Arable Crop Farmers and Climate Change Information Accessibility

The Analysis of Variance (ANOVA) of socio-economic and institutional characteristics of arable crop farmers and climate change information accessibility is presented in Table 6

Table 6: Result of Analysis of Variance (ANOVA) on Socio-Economic and Institutional Characteristics of Arable Crop Farmers and Climate Change Information Accessibility

	Sum of Squares	df	Mean Square	F	Sig.
Regression	8.866	13	0.682	64.811	0.000
Residual	2.578	245	0.011		
Total	11.444	258			

Source: Field Survey, 2023.

Table 6 shows the result of ANOVA of arable crop farmers' access to climate change information. From the result, the F-value is 64.811 is statistically significant at 5%, the p-value of 0.000 is less than the alpha level of 0.05 ($0.000 < 0.05$). This implies that, the group of independent variables shows a statistically significant relationship with the dependent variable (access to information on climate change). This finding agrees with Okoro *et al* (2016) who reported that the overall regression model was significant ($F = 7.189$; $p \leq 0.05$) among farmers in accessing climate change information in Enugu State Nigeria.

CONCLUSION

The research examined the determinants of arable crop farmers' climate change information accessibility in south-south Nigeria. The result Variance Inflating Factor (VIF) concluded that multicollinearity does not exist with high Tolerance level. The research shows that there are more females' arable crop farmers than males with adequate years spent on attaining formal education which foster reading and writing, with sufficient years in farming experience. Majority of arable crop farmers did not belong to any farmers association. Majority of the arable crop farmers received information on climate change through villagers' meetings, radio and television. Multiple linear regression analysis result shows that educational level, farmer association, farming experience, awareness of climate change, radio and television increase the probability of arable crop farmers' accessibility to climate information. ANOVA result indicates that the group of independent variables shows a statistically significant relationship with the access to information on climate change.

RECOMMENDATIONS

From the findings, the following recommendations were made:

v. Arable crop farmers were aware of the existence of extension agents and their mandate to disseminate ready-made information to farmers generally, but arable crop farmers have less access to such information. Hence, there is need to increase the number of extension agents;

vi. Develop mobile applications and SMS services that could deliver weather forecasts, climate tips and farming advice directly to the arable crop farmers phones directly, this would increase the coverage of climate change information accessibility. In addition, there radio and television programmes collaboration with local radio and television stations to broadcast climate-related information and farming tips since they can reach a wide audience;

vii. Government and NGOs could establish community-based climate change information centers where arable crop farmers can access data receive training and exchange knowledge with experts.

Furthermore, there should be improvement in rural infrastructures such as electrification, roads and transportation, to enhance the accessibility of climate change information to rural dwellers; and

viii. Farmers should be encouraged to form farmer associations or cooperatives that can pool resources to access climate change information and implement climate-resilient farming techniques collectively. Involvement of farmers in the designing and implementation of climate information systems to ensure they meet local needs are culturally appropriate.

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REFERENCES

Adeagbo, O., Ojo, T. and Adetoro, A. (2021). Understanding the determinants of climate change adaptation strategies among smallholder maize farmers in South-west, Nigeria. *Heliyon, 7*(2), e06231. DOI:10.1016/j.heliyon.2021.e06231

Alidu, A.-F., Man, N., Ramli, N.N., Haris, N.B.M. and Alhassan. A. (2022). Smallholder farmers access to climate information and climate smart adaptation practices in the northern region of Ghana. *Heliyon, 8*, 1-9. https://doi.org/10.1016/j.heliyon.2022.e09513

Aliyu, H.K., Olawepo, R.A. and Muhammad, S. (2019). Climate change information for farmers in Nigeria: what challenges do women face? *Earth and Environmental Science, 399*, 1-7. doi:10.1088/1755-1315/399/1/012001

Arora, N.K. (2019). Impact of climate change on agriculture production and its sustainable solutions. *Environmental Sustainability*, 2, 95-96. https://doi.org/10.1007/s42398-019-00078-w

Enimu, S., Onome, E.G., Okuma, O.L. and Achoja, F.O. (2022). Choice of climate change adaptation strategies used by food crop farmers in Delta State, Nigeria: The multinomial logistic regression approach. *Nigerian Agricultural Policy Research Journal (NAPReJ), 10*, 143-151.

GeeksforGeeks (2021). Test of multicollinearity. Retrieved from: https://www.geeksforgeeks.org/test-of-multicollinearity/

Imam, M. and Babuga, U.S. (2021). Utilization of climate change information sources among farmers in Nigeria. *Direct Research Journal of Agriculture and Food Science, 9*, 144-148. DOI:https://doi.org/10.26765/DRJAFS5893722617

Muema, E., Mburu, J., Coulibaly, J. and Mutune, J. (2018). Determinants of access and utilization of seasonal climate information services among smallholder farmers in Makueni County, Kenya. Heliyon 4 (11), e00889. DOI:10.1016/j.heliyon.2018.e00889

Nyang'au, J.O., Mohamed, J.H., Mango, N., Makate, C. and Wangeci, A.N. (2021). Smallholder farmers' perception of climate change and adoption of climate smart agriculture practices in Masaba South Sub-county, Kisii, Kenya. *Heliyon, 7*(4), e06789. DOI:10.1016/j.heliyon.2021.e06789

Okoro, J. C., Agwu, A.E. and Anugwa, I.Q. (2016).Climate change information needs of rural farmers in Enugu State. *Journal of Agricultural Extension, 20*(2), 215-232. http://dx.doi.org/10.4314/jae.v20i2.16

Rizwan, M., Ping, Q., Saboor, A., Ahmed, U.I., Zhang, D., Deyi, Z. and Teng, L. (2019). Measuring rice farmers' risk perceptions and attitude: Evidence from Pakistan, Human and Ecological Risk Assessment. *An International Journal*, 1-16 DOI:10.1080/10807039.2019.1602753

Schmidt, M., Gonda, R. and Transiskus, S. (2021). Environmental degradation at Lake Urmia (Iran): Exploring the causes and their impacts on rural livelihoods. *Geojournal 86*, 2149-2163. https://doi.org/10.1007/s10708-020-10180-w

Sow, B.L., Bah, A., Sow, P. and Yaffa, S. (2018). Farmers' awareness and adaptation to climate change in Kaffrine Region of Senegal. *Journal of Environment and Earth Science, 8*(4), 51-59. Retrieved from: https://www.iiste.org/Journals/index.php/JEES/article/view/41911/43156

Tologbonse, E.B., Auta, S.J., Bidoli, T.D., Jaliya, M.M., Onu, R.O. and Issa, F.O. (2010). Farmers' perception of the effects of climate change and coping strategies in three agro-ecological zones of Nigeria. *Journal of Agricultural Extension, 14*(1), 125. DOI:10.4314/jae.v14i1.64080

Vermeulen, J., Aggarwal, P.K., Ainslie, A., Angelone, C., Campbell, B.M., Challinor, A.J. and Wollenberg, E. (2011). Options for support to agriculture and food security under climate change. *Environmental Science and Policy*, 1-9. https://doi.org/10.1016/j.envsci.2011.09.003

World Bank. (2016). Climate information services providers in Kenya. Agriculture global practice technical assistance paper. World Bank group report number 103186-KE; Washington, DC, USA. Retrieved from: https://documents1.worldbank.org/curated/fr/706021467995075539/pdf/103186-REVISED-PUBLIC-AG-GP-TAP-CIS-Providers-in-Kenya-WEB-02292016.pd

MACHINABILITY OF A POLYMERIC COMPOSITE MATERIAL: OPTIMIZATION OF MATERIAL REMOVAL RATE (MRR) AND SURFACE ROUGHNESS

Nteegah, Emmanuel Kpolebabari, Supervised by Dr. D. O.Aikhule Department of Mechanical Engineering, Faculty of Engineering

University of Port Harcourt, Port Harcourt. January, 17th, 2024.

ABSTRACT

Polymeric materials can either be a thermoplastic or thermosetting. Polymeric composite materials possess attractive properties which have made them relevant in the industries including oil and gas industries. However, the components of composite material still possess their individual properties which pose challenge when carrying out machining operation on them to obtain desired surface quality. Therefore, this work is all about the machinability of a polymeric composite material aiming at optimizing material removal rate and surface roughness. To achieve this, six (6) procedures were taken. The first step was the selection of parameters like speed, feed, and depth and their levels as 96rpm, 120rpm, and 480rpm for speed, 0.082mm/rev, 0.163mm/rev, and 0.325mm/rev for feed rates, 1.0mm, 1.5mm, and 2.0mm for depth of cut. This was followed by designing experiment to know optimum number of experiment to perform. Next was the machining of a 75mm in length and 26mm in diameter of a TEFLON polymeric composite material using a Universal Engine Lathe (C620G Model) with a brazed carbide tool according to the number of experiments with their corresponding parameters and levels. Then the volume of material removed and surface roughness were calculated using analytical methods. The results from these calculated figures were used for signal-to-noise ratio and analysis of variance (ANOVA) analyzes using MINITAB STATISTICAL SOFTWARE VERSION 20. Finally, grey relational analysis was conducted using EXCEL SOFTWARE to determine the optimal parameters and values. The results showed that 480rpm spindle speed, 0.325mm/rev feed rate, and 1.5mm depth of cut are the ideal parameters for optimizing material removal rate (MRR) and surface roughness (Ra).

Keywords: Optimization, Machinability, Material Removal Rate, Surface Roughness

1.0 Introduction

Polymeric materials can be thermoplastics or thermosetting in nature. Most of the raw materials that are currently used in industries today are derived from non-renewable sources especially coal and petroleum sources (Abdel-Raout et al., 2021). Polymeric materials for long have been used in their individual natural pure forms (Adewole et al., 2019). Polymeric materials used in oil industry are classified as solid-state polymers and polymers in solution which are used as fluids or additive formulations (Lucas et al., 2009).

However, polymeric materials in their pure natural form have limited applications, hence natural fiber-reinforced composites is rapidly taking centre stage in industries. The only challenge now is the difficulties encounter in machining composite materials due to mechanical anisotropic and heterogenic nature (Lotfi et al., 2019). As compare to conventional process of machining metals, machining of composite materials is more difficult and tedious. Composite materials require superior machining characteristics (Siddappa et al., 2018).

Ozkan et al., (2020) have explained machinability as “the ease or difficulty with which a given material (or group of materials of similar machinability) can be machined, meaning how easy or demanding it is to shape work-piece with cutting tool”. For this, Chegdan & El-Mansori (2019) conducted mechanical tensile and shear tests on UDF/PP specimen in order to relate mechanical behaviour of natural fiber-reinforced thermoplastic composite materials to cutting behaviour.

Shalwan et al., (2022) attributed the machinability behaviour of polymeric composite material to their mechanical, physical properties, chemical treatment, and orientation of fiber layers. The constituents present in composites contribute to machinability of composite materials. These parameters are responsible for surface finish (Alarifi, 2023).

Davim & Reis (2003) conducted machinability study on composite (Polyetherertherketone reinforced with 30% glass fiber-PEEK GF30) using polycrystalline diamond (PCD) and cemented carbide (K20) tools and discovered that PCD is the best because it produces the best surface qualities. Azmi et al., (2013) carried out machinability study of glass fiber-reinforced polymer composites during end milling under different experimental parameters and at different levels using. Taguchi design of experiments method. This was combined with Taguchi analysis and statistical analysis of variance (ANOVA) in order to quantify the effects of spindle speed, feed rate, and depth of cut on material. The end result indicated that feed rate is the dominant factor on surface roughness.

When Yan et al., (2020) studied machinability of three different polymers such as poly (methylmethacrylate) (PMMA), Polyetheretherketone (PEEK), and Polyimide (PI) through dynamic mechanical analysis experiment to evaluate elastic modulus and temperature effect in relation to surface roughness, burrs, and cutting chip characteristics through high-speed micro-milling process. It was observed that PMMA, PEEK, and PI possess good mechanical properties and machinability in visco-elastic state as temperature increases.

Material removal rate and surface roughness are optimized since the two responses are influenced mostly by many factors including, spindle speed, feed rate, and depth of cut among others (Pant et al., 2017). Baek et al., (2001) optimized feed rate in face milling operation using surface roughness models. Models were developed and used to predict machined surface roughness from insert run-outs data and cutting parameters. The results showed that to maximize material removal rate having surface roughness as a constraint, optimal feed rate can be obtained through bisection method.

Borse (2014) studied the effects of process parameters such as cutting speed, feed rate, and depth of cut on surface roughness and material removal rate in dry turning of SAE52100 steel using carbide inserts as tools. He adopted Taguchi L9 orthogonal array in designing the experiments. Models were developed and used to predict surface roughness and material removal rate for the tested work-piece. The results indicated higher cutting speed and feed rate were responsible for the high productivity and finishing.

Machining parts to final dimensions without any extra operations are widely needed now in industries. From the literatures reviewed so far, only very few materials out of the available 50,000 materials their machinability and optimum machining conditions have been determined. Therefore, this work focuses on optimization of material removal rate (MRR) and surface roughness through proper selection of more machining parameters as recommended by Alarifi, (2023) and Wambua et al., (2022) respectively.

2.0 Materials and Methods

There were five (5) basic materials used for this study. Materials selected were thermoplastic polymer (Tetrafluoronitride (TEFLON) or Tetrafluoroethylene (PTFE)) having a length of 1020mm with 26mm diameter, a universal engine lathe-model C620G, a brazed carbide tool, venier caliper, and stopwatch for time taken to machine to the desired diameter.

A length of 100mm of TEFLON was cut from the length of 1020mm and set on the universal engine lathe. Out of 100mm length cut; 20mm was held by the jaw of the lathe while the remaining 80mm was outside the jaw from which, a length of 75mm was machined. Three levels of three input parameters such as spindle speed, depth of cut and feed rate were selected as shown in Table 2.1 below.

Table 2.1: Selected Input Parameter and Levels

Levels	Spindle speed (rpm)	Feed rate (mm/Rev)	Depth of cut (mm)
Low	96	0.082	1
Medium	120	0.163	1.5
High	480	0.325	2

The parameters were selected based on the recommendation by Alarifi (2023) and Wambua et al., (2022)

Taguchi design of experiment method was adopted to ascertain the number of experiments to be conducted and from the result obtained it was found that a total of nine experiments can be conducted. The nine experiments are represented as (3^2) or L9 Taguchi orthogonal array. Teflon material of 26mm in diameter and 100mm in length was used as work-piece. This was set on a universal engine lathe-model C620G and machined to a length of 75mm and 23mm diameter using the different selected machining parameters and the different levels. The time taken to machine the work- piece from the initial diameter of 26mm to final diameter of 23mm and to length of 75mm was recorded at each machining operations using the selected parameters and the different levels. Sample of work-piece, setting on lathe machine and chip produced, machined samples, and samples to be machined are shown below:

  

Work-piece sample The setting on the lathe The machining processes

  

The chip produced Machined sample

The chip produced and samples

 

Machined sample Samples to be

machined

The volume of material removed at each time was calculated using equation 2.1 below: Minaprem, 2023

D 2 D 2

$\pi(\frac{1}{}) L-\pi(\frac{2}{}) L$ $\pi L(D D^{2}$

MRR = 2 2 = 1- Macrae et al.,(2008)

2)

T 4T

[2.1]

Where;

L = The machined length (mm)

D1 = Original diameter of the material used (mm)

D2 = The final targeted diameter of the material used (mm)

T = Time taken to machined to the final desired diameter (min)

While the resulting surface roughness was calculated using equations 2.2 and 2.3 below: Minaprem, 2023

$$hmax = \frac{(So)^2}{8r}$$

[2.2]

Where;

hmax= Maximum surface roughness (mm) So = Feed rate (mm/rev)

r = Nose radius of tool (mm). This is assumed to be depth of cut

$$\text{Average surface roughness, } Ra = \frac{hmax}{4}$$

[2.3]

The equation for MRR (Higher is better) as shown below was used to calculate the signal-to-noise ratio

$$S\,N/ratio = -10\log_{10}\left(\sum_{i=1}^{n}\frac{1}{y_i^2}\right) \quad [2.4]$$

The equation for Ra (Smaller is better)

$$S/N\,ratio = -10\log \quad (\sum^{n} y^2)\ [2.5]$$

Where, 10 i=1 i

n = The number of experiments performed y = The i^{th} trial

Wambua et al., (2022); Sakthievelu et al., (2017).

The equation below was used to calculate the normalization S/N ratio $Max^{(0)}(k)-X^{(0)}(k)$

$X^*(k) =$ xi i [2.6]

i $Max^{(0)}(k)-Min^{(0)}(k)$

xi xi

Source (Wambua et al., 2022 and Desai et al., 2014).

The larger is better normalization S/N ratio $X^{(o)}(k)-Min^{(o)}(k)$

$X^*_i(k) =$ i xi [2.7]

$Max^{(o)}(k)-Min^{(o)}(k)$

xi xi

Th deviation sequences will be calculated using the formula below:

$\Delta O_i(k) = |X^*_o(k)-X^*_i(k)|$ [2.8]

Grey relational coefficient is given by $\gamma(x_o(k), x_i(k))$ and it is calculated using the formula shown below:

$$\gamma(x_o(k), x_i(k)) = \frac{\Delta min+\xi\Delta max}{\Delta O_i(k)+\xi\Delta max} \quad [2.9]$$

Where,

Δmin = The smallest value of $\Delta Oi(k)$ ΔMax = The largest value of $\Delta Oi(k)$

$\Delta Oi(k)$ = The best or ideal value. The average sums of the grey relational coefficient. This is also taken as the normalized comparable sequence and

ξ = The distinguishing coefficient which is taken to be equal to 0.5 for all the response parameters.

Grey relational grade (GRG) is calculated using the formula below:

$$\gamma_{(xo, xi)} = \frac{1}{m} \sum_{i=1}^{m} \gamma_{(xo(k), xi(k))}$$

Where,

$\gamma(xo, xi)$= The grey relational grade and m = The number performance characteristics

3.0 Results and Discussions

Table 3.1: Time Taken for Each Level and Parameter for MRR

S/N	Spindle speed (rpm)	Feed rate (mm/Rev)	Depth of cut (mm)	Time Taken (Minute)
1	96	0.082	1.0	27.28
2	96	0.163	1.5	09.02
3	96	0.325	2.0	05.02
4	120	0.082	1.5	15.03
5	120	0.163	2.0	07.26
6	120	0.325	1.0	05.41
7	480	0.082	2.0	03.55
8	480	0.163	1.0	03.08
9	480	0.325	1.5	01.10

Table 3.2: Taguchi Design Input Output Table for Material Removal Rate (MRR)

S/N	Spindle Speed (rpm)	Feed Rate (mm/rev)	Depth of Cut (mm)	Material Removal Rate (mm^3/min)
1	96	0.082	1.0	19.4360
2	96	0.163	1.5	58.7819
3	96	0.325	2.0	105.6200
4	120	0.082	1.5	35.2769
5	120	0.163	2.0	73.0320
6	120	0.325	1.0	98.0060
7	480	0.082	2.0	149.3556
8	480	0.163	1.0	172.1469

9	480	0.325	1.5	482.0114

Table 3.3: S gnal-to-Noise Rat o for the H gher is better (MRR)

Responses S/N Ratio for MRR

S/N (mm))	Spindle Speed (rpm)	Feed Rate (mm/rev	Dep th of Cut	Material Removal Rate (mm^3/min)	Material Removal Rate (mm^3/min)
1	96	0.082	1	19.4360	25.7721
2	96	0.163	1.5	58.7819	35.3849
3	96	0.325	2	105.6200	40.4749
4	120	0.082	1.5	35.2769	30.9498
5	120	0.163	2	73.0320	37.2703
6	120	0.325	1	98.0060	39.8251

7	480	0.082	2	149.3556	43.4844
8	480	0.163	1	172.1469	44.7180
9	480	0.325	1.5	482.0114	53.6611

Table 3.4: Analysis of Variance (ANOVA) Output for MRR

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	3	124824	41608.1	6.44	0.036
Spindle Speed	1	82303	82303.3	12.74	0.016
Feed Rate	1	42275	42274.9	6.54	0.051
Depth of Cut	1	246	246.0	0.04	0.853
Error	5	32309	6461.8		
Total	8	157133			

Table 3.5: Input output Table for Surface Roughness (Ra)

S/N	Spindle Speed (rpm)	Feed Rate (mm/rev)	Depth of Cut (mm)	Surface Roughness (Ra) (µm)
1	96	0.082	1	0.00021
2	96	0.163	1.5	0.00550
3	96	0.325	2	0.00165

4	120	0.082	1.5	0.00014
5	120	0.163	2	0.00042
6	120	0.325	1	0.00330
7	480	0.082	2	0.00011
8	480	0.163	1	0.00083
9	480	0.325	1.5	0.00220

Table 3.6: Signal-to-Noise Rat o for the Smal er is Better (Surface Roughness)

S/N	Spindle Speed (rpm)	Feed Rate (mm/rev)	Depth of Cut (mm)	Responses Surface Roughness (Ra)	S/N Ratio Surface Roughness (Ra)
1	96	0.082	1	0.00021	73.55561
2	96	0.163	1.5	0.00055	65.19275
3	96	0.325	2	0.00165	55.65032
4	120	0.082	1.5	0.00014	77.07744
5	120	0.163	2	0.00042	67.53501
6	120	0.325	1	0.00330	49.62972
7	480	0.082	2	0.00011	79.17215
8	480	0.163	1	0.00083	61.61844
9	480	0.325	1.5	0.00220	53.15155

Table 3.7: Analysis of Variance (ANOVA) Output for Surface Roughness

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	3	0.000009	0.000003	16.68	0.005
Spindle Speed	1	0.000000	0.000000	0.01	0.937
Feed Rate	1	0.000008	0.000008	45.68	0.001
Depth of Cut	1	0.000001	0.000001	4.34	0.092
Error	5	0.000001	0.000000		
Total	8	0.000010			

Table 3.8: Grey Relat onal Grade (GRG) and Rank

Normalization		Deviation Sequence		Grey Relational Coefficient			
Surface Roughness (Ra)	Material Removal Rate (mm^3/min)	Surface Roughness (Ra)	Material Remove Rate mm^3/min	Surface Roughness Ra)	Material Removal Rate mm^3/min	Grade	Rank
0.96865	0.0000	0.03135	1.00000	0.9410029	0.333333	0.6371681	4
0.86207	0.0851	0.13793	0.91494	0.7837838	0.353371	0.5685776	6
0.51724	0.1863	0.48276	0.81369	0.5087719	0.380608	0.4446901	8
0.99060	0.0342	0.00940	0.96575	0.9815385	0.341121	0.6613298	3
0.90282	0.1159	0.09718	0.88414	0.8372703	0.361236	0.5992533	5
0.00000	0.1699	1.00000	0.83015	0.3333333	0.375898	0.3546159	9
1.00000	0.2809	0.00000	0.71914	1	0.410126	0.7050628	2
0.77429	0.3301	0.22571	0.66987	0.6889849	0.427399	0.5581917	7

0.34483	1.0000	0.65517	0.00000	0.4328358	1	0.7164179	1

4.0 Discussions of the Findings

After performing the necessary experiments, the results are shown in the Tables in section 3.0. From Table 3.1 above, it is observed that short time is needed with high speed and high feed rate to machine polymeric composite material whereas, at low speed of 96rpm, high time is needed. The volume of material removed at each machining operation using the corresponding values are shown in Table 3.2. Table 3.2

shows that maximum volume of 482.011mm^3/min was produced in shortest time of 1.10min as compared with low volume of 19.4360mm^3/min produced in 27.28mins. It is also observed that material removal rate increases as the spindle speed and feed rate increase. This implies that both spindle speed and feed rate influence material removal rate (MRR). These results agreed with Borse (2017) but disagreed with Sakthivelu et al., (2017).

The principle of material removal rate (MRR) is the higher is better. The results generated as shown in Table 3.3 revealed that experiments 9, 8 and 7 have signal-to- Noise ratios of 53.6611, 44.7180, and 43.4844 respectively which further proved the influence of spindle speed and feed rate on material removal rate. This indicated that spindle speed is the most influencing factor for material removal rate, followed by feed rate. This agreed with Pant et al., (2017) in some extent but not completely.

Analysis of variance (ANOVA) was conducted on S/N ratio using MINITAB STATISTICAL SOFTWARE VERSION 20 for material removal rate (MRR) to ascertain the significance and contribution of each of parameter selected towards material removal rate. As shown in Table 3.4, depth of cut has a P-value of 0.853 which is greater than 0.05 and so it has no or less influence on material removal rate. Table 3.4 shows that spindle speed has a P-value of 0.016 which is less than 0.05, while feed rate has a P-value of

0.051 which is slightly greater than 0.05. The results imply that the spindle speed is the most dominant factor on material removal rate, followed by feed rate. This agrees with Azmi et al., (2012).

From the results shown in Table 3.5, experiment 7 has minimum surface roughness of 0.00011µm with a spindle speed of 480rpm, feed rate of 0.082mm/rev, and depth of cut 2.0mm. Maximum surface roughness of 0.00550µm is produced by parameters at experiment 2 which has a spindle speed of 96rpm, feed rate of 0.163mm/rev, and depth of cut 1.5mm. By these results, it is observed that surface roughness increases with decrease in spindle speed and increases with increase in feed rate. This implies that feed rate influences surface roughness as found by Borse (2017) and Davim & Reis (2003).

The results of signal-to-noise ratio for surface roughness are shown in Table 3.6. It utilizes the smaller is better principle. It is a function of mean-square deviation (M.S.D) for output characteristics. As shown in Table 3.6, the less surface roughness we can achieve, the better the surface finish. The value for signal-to-noise ratio of experiments number 7, 4, and 1 respectively are 79.17215, 77.07744 and 73.55561 respectively. From each of these numbers, it is observed that feed rate is constant.

Analysis of variance (ANOVA) was conducted on S/N ratio for surface roughness (Ra) using MINITAB STATISTICAL SOFTWARE VERSION 20 to ascertain the significance and the contribution of each of the parameter selected towards surface roughness. As shown in Table 3.7, spindle speed has a P-value of 0.937 which is greater than 0.05 and this implies that it has no or less influence on surface roughness. From Table 3.7, feed rate has a P-value of 0.001 which is less than 0.05, while the depth of cut and spindle speed have the P-values of 0.092 and 0.937 respectively which is greater than 0.05. This means that feed rate is the most dominant factor on surface roughness, followed by depth of cut. This is in agreement with Sakthivelu et al., (2017)., Pant et al., (2017) but is in disagreement with Wambua et al., (2022) and Borse, (2014).

The optimized ideal parameters and values were obtained from calculated figures using EXCEL SOFTWARE. In this case, Grey relational analysis (GRA) incorporates a lot steps and formulas were applied depending on the objective. The first three of the analysis require the results of material removal rate, surface roughness and signal-to-noise ratios for both responses as shown in Table 3.8. From Table 3.8, it is observed that experiment 9 with spindle speed of 480rpm, feed rate of 0.325mm/rev and depth of cut of 1.5mm has the highest value of S/N ratio for material removal rate to be 53.6611 with a volume of 482.0144mm^3/min of material removed. Grey relational coefficient confirmed that experiment 9 has the highest coefficient and the highest grade value of 0.7164179, followed by experiments 7 and 4 with grade values of 0.7050628 and 0.6613208 respectively. It is shown that the ideal values for optimization are, a spindle speed of 480rpm, a feed rate of 0.325mm/rev, and a depth of cut of 1.5mm and these should be selected in the machining of TEFLON as polymeric composite material.

5.0 Conclusions

The study was to investigate the machinability of polymeric composite material with emphasis on optimization of material removal rate (productivity) and surface roughness (quality). From the research work and after studying the methodologies, a number of conclusions or findings were reached as summarized below:

1. That large volume of material was produced in the shortest possible time. That is 482.0114mm^3/min with a surface quality of 0.00220µm within 01.10min

2. That spindle speed is the most influencing parameters on the material removal rate, followed by feed rate and depth of cut.

3. That the most influencing parameter of surface roughness is feed rate, followed by the depth of cut and spindle speed.

4. That the optimum parameters for surface roughness are 480rpm of spindle speed, 0.082mm/rev of feed rate, and 2mm of depth of cut

5. From grey relational analysis (GRA), it is shown that the optimization values are 480rpm of spindle speed, 0.325mm/rev of feed rate, and 1.5mm of depth of cut with surface roughness of 0.00220µm.

REFERENCES

Abdel-Raout, M.E., Keshawy, M., Hasan, A.M.A (2021): Green Polymers and Their uses in Petroleum Industry, Current State and Future Perspectives. Crude Oil New TechnologiesandRecentapproaches.

Adewole, J.K &Muritala, K.B (2019): Some Applications of Natural Polymeric Materials in Oilfields Operations: a review. *Journalof Petroleum Explorationand Production Technology*.9:2297-2307

Alarifi, I.M (2023): A Review on Factors Affecting Machinability and Properties of Fiber-Reinforced Polymer Composites.JournalofNaturalFibers, 20(1), 215-230

Azmi, A.I (2013): Machinability study of Fiber-reinforced matrix composites.Centerfor AdvancedCompositesMaterials, UniversityofAuckland, New Zealand.

Baek, D.K., Ko, T.J., Kim, H.S (2001): Optimization of Feed rate in a Face Milling Operation using a Surface Roughness Model. *International JournalofMachine Toolsand Manufacture*, 41(3), 451-462

Borse, S.C (2014): Optimization of Turning Process Parameter in Dry Turing of SAE52100 Steel. International Journal of Mechanical Engineering and Technology (IJMET), 5, (12), 1-8

Chegdani, F &Elmansori, M (2018): Mechanics of Material Removal When Cutting Natural Fiber-reinforced Thermoplastic Composites. Polymer Testing, 67, 275-283

Davim, J.P & Reis, P (2003): Machinability study on Composite (Polyetheretherketone Reinforced with 30% Glass fiber-PEEK GF 30) using Polycrystalline diamond (PCD) and Cemented Carbide (K20) tools. *International Journal of Advanced Manufacturing Technology,* 23, 412-418

Desai, S., Chavan, A., Pawade, R., Brahmankar, P.K (2014): Multi-attribute Optimization in CNC Turning of PEEK Polymer using Grey Relational Theory. International Conferenceon Advancesin Designand Manufacturing (ICAD&M'14)

Lotfi, A., Li, H., Dao, D.V., Prusty, G (2019): Natural Fiber-reinforced Composites: A review on Material, Manufacturing, and Machinability. Journalof Thermoplastic Composite Materials1-47

Lucas, E.F., Mansur, C.R.E., Spinelli, L., Queiros, Y.G (2009): Polymer science applied to petroleum production. Pure Appl. Chem., 81, (3), 473-494

Macrae, M., kalejaiye, A.O., Chima, G.U., Gaba, M.O (2008): New General Mathematics for Junior Secondary Schools, 4th Edition, Pearson Education Limited.

Minprem, (2023): Micro, Nano, Precision & Manufacturing Ltd

Ozkan, D., Gok, M.S., Karaoglanli, A.C. (2020): Carbon Fiber Reinforced Polymer (CFRP) Composite Materials, Their Characteristic Properties, Industrial Application Areas and Their Machinability.SpringerNatureSwitzerlandAG

Pant, G., Kaushik, S., Rao, D.K., Negi, K., Pal, A., Pandey, D.C (2017): Study and Analysis of Material Removal Rate on Lathe Operation with Varying Parameters from CNC Lathe Machine. International Journal of Emerging Technologies, 8(1), 683-689

Sakthivelu, S., Anandara, T., Selwin, M (2016): Multi-objective Optimization of Machining Conditions on Surface Roughness and MRR during CNC End Milling of Aluminium Alloy 7075 using Taguchi Design of Experiments. Mechanics and MechanicalEngineering, 21(1), 95-105.

Shalwan, A., Alsaeed, T., Yousif, B. (2022): Machinability of Polymeric Composites and Future Reinforcements-A Review. *Journal of Materials Science and ChemicalEngineering,* 10,40-72

Siddappa, P.N., Shivakumar, B.P., Yogesha, K.B., Mruthunjaya, M., Hanmantraygouda,

M.B (2018): Machinability Study of Al-TiC Metal Matrix Composite. MATECWeb of Conferences,144, 03001.

Wambua, J.M., Mwema, F.M., Tanya, B., Jen, T (2022): CNC Milling of Medical-Grade PMMA: Optimization of Material Removal Rate and Surface Roughness. *International Journal of Manufacturing, Materials, and Mechanical Engineering*, 12.(1), 34-50

Yan, Y., Mao, Y., Li, B., Zhou, P (2020): Machinability of the Thermoplastic Polymer: PEEK, PI, and PMMA.Polymers,13, 69

Effect of Chaya (*Cnidoscolus Aconitifolius*) Leaf Extract Supplementation on Performance, Carcass characteristics and Serum Biochemistry of Broiler Birds

Ndukwu, E. C[1]., Ironkwe, M.O[2] and Ekine, O. A[2].

[1]Department of Experimental Pharmacology and Toxicology, University of Port Harcourt, Nigeria
[2]Department of Animal Science, University of Port Harcourt, Nigeria.

Corresponding author's Email: Edwin.ndukwu@uniport.edu.ng.

ABSTRACT

The aim of this study was to determine the potentials of Chaya leaf extract as test ingredient to improve performance, carcass characteristics as well as serum Biochemistry indices of broiler birds. Chaya leaf extract was used as test ingredient via drinking water in the 56 days experiment. 180-day-old Agrited broiler chicks were used in the study and randomly assigned into 4 dietary treatments that were replicated 3 times with fifteen (15) birds per replicate in a Completely Randomized Design (CRD) experiment. The birds were given varying levels of Chaya leaf extract from starter to finisher phase with a known weight of Chaya leaf per10 litres of water at 20gram, 40gram, and 60 grams respectively representing treatments (2,3 and 4). The control (T_1) was given equal volume of normal water, the quantity of Chaya leaf as well as aqueous extract offered to the birds increased as the birds advances in weight and age. Phytochemical and proximate determination of Chaya leaf showed presence of some bioactive components. The initial weights of the birds were determined before the commencement of the study as well as the final weight at the end of the experiment respectively. The results indicate that the inclusion of 40 percent Chaya leaf extract in broiler nutrition improved performance parameters and liver enzymes (AST, ALT, and ALP) of broiler chickens. Considering the nutritional benefits of the Chaya plant, its inclusion in the diets of broiler chicken is recommended.

Keywords: Chaya Leaf, Broilers, Performance

Introduction

Chaya plant is a phytobiotic leafy green vegetable plant that can grow upto the height of about 6 meter tall and belongs to Euphabiacea family. The plant is a perennial plant and originated from Central and Southern America (Mexico) precisely (Kulathuran *et al.,* 2014 and Zarmai, 2017). Chaya plant has been found growing in many tropical and subtropic regions of the world including Nigeria.

Phytobiotic plants such as Chaya plant is one of the green vegetables used in the daily nutrition of man and poultry in Nigeria due to its higher nutritional and medicinal values.

It is called blood booster, Efo-Iyanapaja and "hospital" too far in the South East, South West and South-South regions of Nigeria (Ndukwu *et al.;* 2018 and Zarmai *et al* 2020). Chaya plant has been used as food, feed additive, alternative to antibiotics and immunomodulating agent to strengthen immune system and control the activities of pathogenic organisms as well as other unfavorable conditions in man and farm animals. Chaya leaf extract is known to contain bioactive components such as saponin, tannins, phenols and alkaloids (plant secondary metabolites) and Phytobioactivity profile such as antioxidants, antimicrobial, anti-proliferate, anti-inflammatory and immuno-modulatory properties that have the potential to stimulate the immune system of broiler birds for better performance and improve health (Grashorn, 2010 and Oni *et al.,* 2018).

The leaves and shoots of Chaya plant have been used to fortify broiler diets, for prophylaxis and treatment of many diseases such as diabetes, obesity, insomnia, hemorrhoids and kidney stone (Oni *et al,* 2018 and Kulathuran *et al,* 2014). Chaya plant is more nutritious than other green vegetable plants such as spinach (Amaranthus *sp*), cabbage (Brassica *sp*) and lettus (lactuca *sp*). Chaya leaves contain mineral components, amino acids and vitamins such as vitamins C and D which are major sources of antioxidant (Victor *et al,* 2016, Marina Silalahi, 2021 and Ndukwu *et al,* 2018). The aim of this study was to investigate the potentials of bioactive constituents of Chaya leaf aqueous extract to stimulate performance, Carcass characteristics and health status of broiler chicken.

However, Chaya leaf Extract has the potential to neutralize effects of growing microbial resistance caused by incessant use of antibiotics in poultry production.

Materials and Method

This study was conducted at the poultry section of the University of Port – Harcourt Teaching and Research Farm, Choba, Rivers State. The area is located at latitude 4^0N and longitude 7^0E with an average temperature of 26.4^0C and mean annual rainfall of 2708mm.

Identification of Chaya plant (Test Ingredient)

The chaya plant (test ingredient) was properly identified and given a voucher number: UPHE 0586 at the Herbarium of the Department of Pharmacognosy and Phytotherapy, University of Port Harcourt by b7y an expert.

Collection and Preparation of Test Ingredient

After harvest, the leaves were washed with clean water to get them rid of dust and sun-dried on a mat for 2 days. The Chaya leaves were sourced from the surroundings of Mgbuoba Port Harcourt and Pharmaceutical Garden of University of Port-Harcourt, Rivers State, Nigeria. The leaves were later gathered and grinded with electronic grinding machine as a known quantity of the leaves were macerated with equal volume of water (aqueous extract) at 20gram of Chaya leaf, 40 gram and 60gram of Chaya leaf respectively representing treatments (2,3 and 4) that vary in the concentration of the aqueous leaf extract given to broiler chicken.

While the control (T_1) was given the same volume of normal water. The quantity of leaves and volume of water used in the study were progressively increased on weekly basis as the birds advanced in age and body weight. The aqueous extract was allowed for 3 hours to settle and filtered. The filtrate was stored in a 20 litre jerry can for use in the eight (8) Weeks Study. 180 day old Agritted broiler chicks were used in a study and assigned randomly in 4 treatment groups with 45 birds per treatment.

The birds were starved for 12 hours following the end of experiment as two birds were sacrificed from each replicate and blood samples were collected for laboratory analysis and evaluation of organs and carcass weight. Non-EDTA bottles were used to collect blood serum for serum biochemical analysis as the samples were stored in ice water before taking to the laboratory for analysis.

Quantitative phytochemical screening of chaya leaf extract.

Quantitative phytochemical screening shows the amount of each of the bioactive constituent present in the extract. Quantitative phytochemical was done using a modified method as described by Jayashree and Gopukuma.(2018).

Quantitative estimation of saponins

Water and methanolic extracts were dissolved in 80% methanol and 2 ml of vanillin in ethanol was added, mixed well as the 2ml of 77% sulphuric solution was added, mixed well and heated on a water bath at 600ºc for 10 minutes, absorbance was measured at 454nm against reagent blank.

Diosgeninis was used as standard material and compared the assay with Diosglyin equivalents. It is important to know that the quantitative phytochemical screening commences after qualitative phytochemical screening.

Test for Flavonoid

The flavonoid content was estimated by Aluminium chloride method using catechin as a standard. 1m1of the test sample and 4ml of water were added to a volumetric flask (10ml volume). After 5 minutes 0.3 of 5% sodium nitrite, 0.3 ml of 10% Aluminum chloride was added. After 6 minutes incubation at room temperature, 2ml of 1 m sodium hydroxide was added to the reaction mixture. Immediately the final volume was made up to 10ml with diluted water. The absorbance of the reaction mixture was measured at 510nm against the blank spectrophotometriclly equivalents (mg catechin/g dried extract).

Test for Alkaloids:

1 ml of plant extract was added to 5ml ph4.7 phosphate buffer together with 5ml BCG solution and shake in a mixture with 4 ml of chloroform. The extracts were collected in a 10-ml volumetric flask and then diluted to adjust volume with chloroform. The absorbance of the complex in chloroform was measured at 470nm against blank prepared as above but without extract. Atropine is used as a standard material and compared the assay with atropine equivalents.

Test for steroids

1 gram of the extract was macerated with 20mlof ethanol and filtered as 2ml of chromagen solution was added to the solution and allowed to stand for 30 minutes. The absorbance was read at 550nm.

Test for glycosides

1 gram of the extract was macerated with 50ml of distilled water and filtered.4ml of alkaline pirate solution was added to the extract. The mixture was boiled for 5minutes and allowed to cool and the absorbance was observed at 490nm.

Management of Birds and Diets

A total of 180 day old broilers were used in the study that lasted for 8 weeks. The were randomly allotted into 4 treatment groups that were replicated 3 times with fifteen (15) birds each in a Completely Randomized Design (CRD) experiment. The birds were raised under deep litter system with normal housing temperature. The birds were fed ad libitum with formulated broiler starter and finisher diets together with aqueous extract of Chaya leaf that was given via drinking water at varying levels. The Chaya leaf extract was given at the following levels of concentration; 20g CLE/10lit, 40gCLE/10lit and 60gCLE/10lit) representing treatments 2, 3 and 4, except the control (T_1) that was given equal volume of normal water. However, all the dietary treatments were given Chaya leaf extract as alternative t antibiotics and were raised free of antibiotics. Both quantitative phytochemical investigation and proximate determination were carried out on the Chaya leaf to quantify its bioactive and nutritional profile.

Data Collection

Data collection was done on the following parameters such as initial body weight, final body weight, weight gain, feed intake, water intake, feed conversion ratio, mortality rate, carcass and organ weight as well as serum biochemistry indices. The body weight was measured on weekly basis to determine weight gain of the birds. Feed intake was determined by weighing out left-over feeds from the quantity offered on daily basis. Blood serum was used to determine the effects of Chaya leaf extract on serum biochemistry indices.

Table 1: Composition of experimental diet for Broiler Chicken

Ingredients	**T_1(0g)**	**T_2(20g)**	**T_3(40g)**	**T_4 (60g)**
Maize	**51.5**	**51.5**	**51.5**	**51.5**
Soya bean	10	10	10	10
Groundnut cake	10	10	10	10
PKC	4.5	4.5	4.5	4.5
Fish meal	8.1	8.1	8.1	8.1
Wheat bran	4.7	4.7	4.7	4.7
Bone meal	3	3	3	3
Palm oil	4.4	4.4	4.4	4.4
Vitamin Pmx	2.5	2.5	2.5	2.5
Methionine	0.8	0.8	0.8	0.8
Lysine	0.2	0.2	0.2	0.2

Salt	0.3	0.3	0.3	0.3
Total	**100**	**100**	**100**	**100**
% Conc. of Chaya Lead Extract	0	2.67	5.3	8
Nutrient Calculated				
CP	20.18	20.18	20.18	20.18
ME	3004.32	3004.32	3004.32	3004.32
CCF	4	4	4	4
Oil	7.94	7.94	7.94	7.94
Lysine	1	1	1	1
Methionine	041	041	041	041
Calcium	1.65	1.65	1.65	1.65
Phosthorus	1.05	1.05	1.05	1.05

Test ingredient (Chaya Leaf Extract) in drinking water.

Contains in the following per kg: vitamin A: 23000000 IU, vitamin D: 1,100000vitamin E: 1800 IU, vitamin K: 800mg, vitamin B12: 6mg, niacin: 7500mg, folic acid: 450mg, pantothenic acid: 3000mg, biotin: 40mg, antioxidant: 3000mg, cobalt: 80mg, copper: 2000mg, iodine: 400mg, iron: 1200mg, manganese: 1800mg, selenium: 60mg and zinc: 14000mg.

Table 2: **Volume of Water (Aqueous Chaya Leaf Extract) used as Test Ingredient for Broiler Starter phase during the Study**

		T_1(0g)	T_2(20g)	T_4(40g)	T_6(60g)
Starter phase	1st week				
		7.5 lit	7.5 lit	7.5 lit	7.5 lit
	2nd week	(0g)	(30g)	(50g)	(70g)
		9.5 lit	9.5 lit	9.5 lit	9.5 lit
	3rd week	(0g)	(40g)	(60g)	(80g)
		10.5 lit	10.5 lit	10.5 lit	10.5 lit
	4th week	(0g)	(50g)	(70g)	(90g)
		12 lit	12 lit	12 lit	12 lit

Table 3. Volume of Water (Aqueous Chaya Leaf Extract) used as Test Ingredient for Finisher phase during the Study

		T_1(0g)	T_2(60g)	T_4(80g)	T_6(100g)
Finisher Phase	5th week	13.5 lit	13.5 lit	13.5 lit	13.5 lit
	6th week	(0g) 15 lit	(70g) 15 lit	(90g) 15 lit	(110g) 15 lit
	7th week	(0g) 16.5 lit	(80g) 16.5 lit	(100g) 16.5 lit	(120g) 16.5 lit
	8th week	(0g) 18 lit	(90g) 18 lit	(110g) 18 lit	(130g) 18 lit

Statistical Analysis:

All collected data were subjected to Analysis of Variance Technique (ANOVA) using the statistical Package for Social Science (SPSS version 23). Duncan multiple range test was used for separation of means among treatments.

Results and Discussions

Quantitative phytochemical screening of chaya leaf aqueous extract.

The result in Table 4 showed that the quantitative phytochemical composition of bioactive components in the extract as well as their degree of abundance of these phytochemical in mg/100g of the extract as follows; 1.97 of saponins, 3.94 of flavonoid, 2.05 of steroid, 3.61 of Alkaloid and 2.82 of glycoside.

The result showed that flavonoid and alkaloid were higher in amount in the extract than other bioactive ingredients. Flavonoid are known for their antioxidant activity, antimicrobial and antihyperglycemic properties (Iwuji *et al,* 2014 and Akin-Osaniye *et al,* 2015). This result is in agreement with the findings (Ivah-Moises Sanchez-Hermendez *et al,* 2007) who reported that flavonoid contains antioxidant property that would neutralize free radicals and protect birds from developing heart disease and cancer related cases.

Saponins possessed high bioactivity profiles like antidiabetic, antihyper cholesterol, anticarcinogenic, hypotensive and cardiac depressant properties to prevent cardiac failure in broiler chickens (Iwuji *et al.,* 2014 and Awoyinka *et al,* 2017*)*. Soponins play a vital role as a hemolytic agent which regulates the blood profile of monogastric animals such as broiler chickens to inhibit bleeding and blood loss during injury. This report agrees with the findings of (Alikwe and Owen, 2014 and Kim *et al,* 2014) that saponins had properties of precipitating and coagulating red blood cell as well as antihyperglycaemic activity. Cardiac glycoside has been known for its anti- depressant and anti-cholesterol properties. This result was in tandem with the findings of (Ndukwu *et al,* 2018) who reported that cardiac glycoside had the potential to regulate blood chemistry such as the level of cholesterol and triglycerides in the blood of broiler chicken that might be harmful for normal function of the heart. Alkaloids are also known for their antihypertension and detoxifying properties (Mordi and Akanji, 2012). The phytobioactivity profile of steroid is not yet clear, and that does not in any way affect the nutritional and medicinal efficacy of the aqueous chaya leaf extract of *Cnidoscolus aconitifolius*.

Table 4:Result of the quantitative phytochemical screening of chaya leaf aqueous extract

Phytochemcial (mg/100g) components	Concentration Value
Saponin	1.97
Steroid	2.05
Flavonoid	3.90
Alkaloid	3.61
Glycoside	2.81

Proximate Composition of Chaya leaf

The proximate determination revealed that Chaya is a nutritious plant. It contains a good dry-matter content and high amount of crude protein, ash, crude fibre, energy and moisture necessary to meet the nutritional requirements of broilers.

The results shown on Table 5, indicates the proximate composition of Chaya leaf which was higher compared with the values obtained by Oni *et al, (*2018). Over the years, Chaya leaf has been used as food for man and as an under utilized non-conventional feed stuff for poultry production in Africa. The result showed that the value of dry-matter content obtained in the study was comparable and falls within the range value (91.27±0.0) obtained by Zarmai *et al* (2017). This is a indication that Chaya leaf extract is high in nutrient content and can satisfy the nutritional requirements of broiler chicken needed for effective performance. The value (8.25%) obtained for moisture content in this study was less than the value (11.42%) reported by (Obasa *et al,* 2017).

Low moisture content of a feed stuff is very vital, and can inhibit the growth of microorganisms as well as increase their storage life (Emmanuel *et al,* 2011). The result showed a crude protein value (18.56%) that was higher compared with the value (16.4lg/100g) reported by (Javid *et al,* 2009) in Amaranthus viridus leaf. Higher amount of crude protein obtained in the Chaya leaf is an indication that aqueous Chaya leaf is a good source of protein. The value obtained for crude lipid in this study was 6.25% which was higher than the value (4.34±0.16) reported by (Adamu *et al,* 2020), and lower than the value (6.85±0.017) reported by Zarai *et al(* 2017).

However, the value obtained for crude lipid in this study showed that Chaya leaf is highly palatable as a result of its fat content. Fat increases food palatability by absorbing and retaining flavours (Antia *et al,* 2006). Taking excess fat is risky and has certain health implications such as cardiovascular disorder, atherosclerosis, diabetes and cancer (). The result showed that the value of crude fibre (9.15%) obtained in this study was higher compared with the value (8.64±0.017) reported by Zarmai *et al, (*2017). Dietary fibre reduces serum cholesterol level, diabetes, cancer and constipation. The value obtained for Ash (11.25%) in this study was higher compared with the value (9.27±0.16) reported by Adamu *et al* (2020). Studies have revealed that the level of Ash content in a feed stuff is as well as the reflection of mineral content preserved in the feed. The value obtained for nitrogen free extract falls within the range values (55.50±0.24 and 47.22±0.04) reported by (Zarmai *et al,* 2017 and Adamu *et al,* 2020). High carbohydrate value reported in this study is an indication that Chaya leaf is a good source of energy for human and animal nutrition. The result showed a calorific value (275.52KCol/100g) which is slightly lower compared with the value (276.04±0.45) reported by Adamu *et al* (2020).

Table 5: Proximate Composition of *Cnidoscolus aconitifolius* (Chaya leaf)

Parameters	percentage conc (%)
Dry matter	91.75
Moisture	8.25
Crude protein	18.51
Crude lipid	6.25
Crude fibre	9.15
Ash	11.25
Nitrogen free extract	49.5
Calorific value (Kcal/100g)	275.52

Growth Performance of Broiler Chickens

The effect of Chaya leaf extracts on growth performance of broilers showed a significant difference ($P<0.05$) in the broiler starter phase among the treatments except mortality rate. Treatment 3 had the highest body weight, weight gain and best feed conversion ratio (FCR). The result showed that effect of Chaya leaf extract on broiler starter followed a similar trend with the broilers at the finisher phase. Treatments 3 still had the highest final body weight, weight gain and least feed intake value with best feed conversion ratio (FCR) compared to the control (T_1) and other dietary treatments (2 and 4). This suggests that 40g of Chaya leaf extract inclusion improved performance and higher weight gain in broiler chicken. This result was in agreement with the findings of (Oni *et al,* 2018) who reported improvement in body weight gain of pullet chicks fed phytomix (garlic, ginger and Chaya leaf meal) inclusion. However, palatability and digestion of the aqueous Chaya leaf extract by endogenous enzyme secretion might have as well improve nutrient role for development of digestive system, muscle tissue accretion, immune system and growth performance. The result showed a reduced feed intake value and better feed conversion ratio (FCR) among the dietary treatment groups compared to the control group (T_1).

This signifies the nutritional potentials of Chaya leaf extract to enhance better feed utilization efficiency in the dietary treatment groups. This result was similar with the reports given by Elagib *et al (*2013) and Oni *et al* (2018)who respectively reported reduced feed intake, improved feed conversion ratio (FCR) and feed utilization efficiency in broiler chickens fed with varying levels of phytomix inclusion.

Water intake increased in the dietary treatment groups compared with the control (T_1). Treatment 1 had the least water intake followed by treatments (4 and 2). Treatment 3 had the highest water intake value to achieve higher body weight gain, better FCR and feed utilization efficiency. This result signifies that the test ingredient (Chaya leaf extract) improved water intake of broiler chicken in the dietary groups. Mortality rate was higher in the control (T_1) compared to dietary treatment groups (2,3 and 4). This result justifies the phytobioactive potentials of Chaya leaf extract to improve liveability of broiler birds. This report was in agreement with the findings of (Donkoh *et al,*1999) who reported decreased mortality rate in broiler chickens fed diets containing Chaya leaf (CLM). The phytobioactivity (antioxidant, anti-inflammatory and antimicrobial) potentials of Chaya leaf extract were responsible for low mortality rate in the dietary groups compared to control group (T_1).

Table 6: Effect of Chaya Leaf Extract on Growth Performance of Broiler Finisher

Parameters (g)	T_1(0g)	T_2(20g)	T_3(40g)	T_4(60g)
Initial weight (g)	46.00 ±0.00	46.40 ±0.20	46.00 ±0.00	46.00 ±0.00
Final weight (g)	2903.44 ±49.69^{c}	3013.62 ±49.72^{b}	3130.67 ±10.61^{a}	2925.84.±42.75^{c}
Weight gain (g)	2857.44 ±49.84^{b}	2967.22±49.84^{a}	3085.13 ±49.95^{a}	2878.57±43.27^{b}
Feed intake (g)	3878.00 ±25. 98^{b}	3573.24±29.47^{a}	3586.20±27.19^{a}	3576.03±20.78^{ab}
Water intake (ml)	4303.52±72.27^{c}	4553.04±43.66^{ab}	4648.89±35.10^{a}	4395.32±45.43^{b}
FCR	1.35±0.03^{b}	1.21±0.01^{a}	1.14±0.03^{a}	1.23±0.02^{b}
Mortality (%)	2.2^{a}	1.2^{b}	1.2 ^{b}	1.6^{ab}

^{a,b,c} Means within each row bearing different superscript differ significantly ($P<0.05$)

Serum Biochemistry

The result of this study revealed that values obtained for total protein were higher in the dietary treatments (2,3 and 4) compared to control group (T_1). Treatment 4 had the highest value followed by treatments (2 and 3). This result confirms the potentials of Chaya leaf as a good source of protein, which has improved the protein requirements of broiler chicken to maintain good health, colloid osmotic pressure, transport of dietary nutrients, mineral and hormones. This result agrees with the findings of (Piotrowska *et al,* 2011) who reported that in poultry birds, serum protein promotes maintenance of colloid osmotic pressure, morbidity of dietary nutrients, vitamins, minerals and hormones as well as biosynthesis of enzymes and immune system. Higher protein and albumin level suggest enhanced liver function which as well confirms the hepatoprotective activity of aqueous Chaya leaf extract.

The values obtained for albumin showed no significant difference ($P< 0.05$) among the treatments. Higher albumin level was observed in treatment 4 compared to control (T_1). This result signifies the ability of Chaya leaf extract to improve performance and health status of broiler chicken. Albumin play important roles in delivering essential nutrients to body cells and as a result, enhance tissue growth and healing.

This report is synonymous with the findings of (Piotrowska *et al,* 2011) that albumin provides appropriate amino acids necessary for tissue protein synthesis, quick osmotic growth as well as enhance binding of toxic and free radicals to prevent oxidative stress and cell damage.
For total bilirubin, values obtained showed slight significant difference ($P<0.05$) among the treatments. Treatment 4 had the highest value followed by treatments 2 and 1, while treatment 3 had the least value. Conjugated bilirubin followed a similar trend with total bilirubin. Treatment 4 had the highest value. This result signifies the capacity of Chaya leaf extract to stimulate normal function of the liver without any adverse effects.

The values obtained for serum urea concentration showed a reduction in urea level in the dietary groups compared to control (T_1). Treatment 4 had the best value followed by treatments 3, 1 and 2. This result suggest that Chaya leaf extract have the potential to reduce serum urea concentration in blood to stimulate digestion, and enhance the normal function of liver and kidney. A similar report was made by (Oni *et al,* 2018) that pullet chicks fed phytomix inclusion (garlic, ginger and Chaya leaf meal) indicated a reduced urea concentration and enhanced digestive stimulating effect for better digestion, absorption and utilization of protein in the dietary groups without, any detrimental effects on the liver and kidney.

The values obtained for creatinine concentration in the dietary groups were comparable with the values obtained in the control (T_1). Creatinine is a useful tool to determine kidney function. Treatments (4 and 3) had the best values. The result confirms the potentials of Chaya leaf extract to enhance renal function of broiler birds. Higher creatine values were obtained in the control (45.33±4.62) and treatment 2 had highest creatinine value (48.33±2.24) which might have caused by differences in muscular activity and unfavourable environmental conditions among birds in the treatments.

This result agrees with the findings of (Marcous Barcellos Café *et al,* 2012) who reported (1.41) highest creatinine level in his studies with broilers at 35 days of age and that creatinine level increases by age as well as muscular activity. The result showed that values of mineral components in the dietary groups were comparable with the control (T_1). This result does not in anyway contradict the potentials of Chaya leaf extract as good source of proteins, minerals and vitamins for production of antioxidant in broiler chickens.

Table 7: Effect of Aqueous Leaf Extract of Chaya on Serum Biochemistry of Broiler Chicken

Parameters (g)	T_1(0g)	T_2(20g)	T_3(40g)	T_4(60g)
Total Protein (g/L)	39.33 ±8.92^b	51.83 ±1.09 ^{a}	47.16 ±4.12^a	52.16 ±1.66^a
Albumin (g/L)	29.33±1.69	28.47 ±5.03	29.33±3.60	33.50.±1.80
Total bilirubin (umol/L)	8.68 ±0.36^{ab}	8.68±0.40^{ab}	7.61±0.51^b	9.31±0.23^a
Conjugated bilirubin (umol/L)	5.97±0.19	5.48±0.23	4.53±0.50	6.82±0.19
Urea (mmol/L)	2.16±0.23 ^{a}	2.18±0.33^a	2.00±0.14^a	1.76±0.54^b
Creatinine (umol/L)	45.33±4.62^a	48.33±2.74^a	44.33±2.02^a	38.33±2.09^b
HCO_3 (mmol/L)	24.33±1.16	25.16±0.17	24.50±1.25	27.66±0.88
Potassium (mmol/L)	3.47±0.19	3.43±0.24	3.57±0.18	3.31±0.18
Sodium (mmol/L)	129.83±6.96^b	128.83±8.53^b	133.00±7.26^a	125.33±5.67^b
Chloride (mmol/L)	70.16±3.91	69.67±0.83	67.83±2.46	70.33^a±5.10

^{a,b,c} Means within each row bearing different superscript differ significantly (P<0.05

Lipids and Enzymes

The values obtained for cholesterol showed no significant difference in the values obtained in the dietary group compared with the values obtained in the control group. This report does not contradict the phytobiactive potentials of Chaya leaf extract as antihyper cholesterolemic agent. This may be due to differences in metabolic processes of Chaya leaf extract among the treatments as well as differences in the physiologic functions of the birds.

The values for triglyceride followed the same trend with cholesterol among the treatments. Triglycerides are known to store unused calories and supply energy to the body of broiler birds. There was a report by (Jannatara *et al,*2020) that excessive

deposition of abdominal fat in chicken is due to high intake of unsaturated fat and cholesterol which can cause problem particularly cardiovascular diseases, loss of dietary energy as well as decrease in carcass yield which may negatively affect its acceptability by health-conscious consumers. The values obtained for HDL showed that treatment 4 had higher value followed by treatments (3 and 2) while treatment 1 had the least value. HDL absorbs cholesterol in the blood and carry it to the liver where it is being detoxified and flush from the body to lower the risk of cardiac failure in broiler chicken. This result showed the anti-hypercholesterolemic effects of Chaya leaf extract in lowering cholesterol and triglycerides. This report agrees with the findings of (Adaramonye *et al,* 2011 and Ndukwu *et al*, 2018) that Chaya leaf extract had the capacity to reduce cholesterol and triglyceride levels in weaner rabbits and wistar rats respectively.

For AST (Aspartate amino transferase) the values obtained were higher in the dietary groups, when compared with the control group. Treatments 3 had the best value (38.33±3.59) followed by treatments (2 and 1). This result affirms the hepatoprotective potentials of Chaya leaf extract. Higher AST value obtained in treatment 4 (46.16±1.20) may be due to differences in metabolic processes of Chaya leaf and in physiologic functions of the birds. This result is in tandem with the findings of Kailash, (2018) that increase in AST level may be due to unseen abnormalities as well as high cholesterol which does not produce any harmful effects except mere changes in serum enzyme level. However, the result showed slight significant difference ($P<0.05$) for both ALT and ALP values obtained in the dietary groups (2,3 and 4) compared to control (T_1). Chaya leaf extract stimulated reduction in the value of liver enzymes. (ALT and ALP) respectively, with treatments (3 and 2) maintaining the least values (4.18±0.27 and 120.50±1.04). This result agrees with the findings of Oni *et al,* (2018) who reported high ALT values in pullet chicks fed with phytomix (garlic, ginger and Chaya leaf meal) inclusion. ALT is essential for transformation and detoxification of toxicants such as ROS and Xerobiotics.

Table 8: Effect of Chaya leaf extract on Lipids and Enzymes in Broiler Chicken

Parameters (g)	**T_1(0g)**	**T_2(20g)**	**T_3(40g)**	**T_4(60g)**
Total cholesterol (mmol/L)	3.08 ±0.27	3.33 ±0.26	3.36 ±0.22	3.11 ±0.10
Total triglycerides (mmol/L)	0.72 ±0.06	0.66 ±0.03	0.73±0.03	0.64.±0.23
HDL (mmol/L)	1.22 ±0.02^{b}	1.700±0.34^{a}	1.39±0.07^{b}	1.73±0.50^{a}
LDL (mmol/L)	2.19±0.23	2.94±0.51	2.29±0.26	2.13±0.16
VLDL (mmol/L)	0.33±0.03	0.37^{a}±0.06	0.29^{a}±0.00	0.33^{a}±0.03
AST (U/L)	43.83±2.13^{a}	41.83±2.09^{a}	38.33±3.59^{b}	46.16±1.20^{a}
ALT (U/L)	6.68±0.75^{a}	4.60±0.23^{b}	4.18±0.27^{b}	4.37±0.29^{b}
ALP (U/L)	126.17±2.58^{b}	120.50±1.04^{c}	126.17±0.67^{b}	196.16±36.83^{a}

^{a,b,c} Means within each row bearing different superscript differ significantly (P<0.05).

Carcass Characteristics and Organ Weight of Broiler Chicken

The result of this study showed a significant difference (P<0.05) in dress weight values among the treatments. Treatment 3 had highest dress weight value. This result signifies the potentials of Chaya leaf extract which improved dress weight of broiler chickens in the dietary groups compared to control (T_1). This result is tandem with the findings of Oni *et al,* (2018) who reported improved body weight gain in pullet chicks fed phytomix inclusion. However, the positive effects of Chaya leaf extract on palatability and digestion stimulation by endogenous enzymes secretion for nutrient enhancement and development of digestive system, muscle tissue accretion, immune system and improve growth performance cannot be over emphasized. The values obtained for thigh weight showed significant difference (P<0.05) among the treatments. Treatment 4 had the highest value followed by treatments (3 and 2). There was no significant difference observed in the values obtained for Drumstick, breast weight, back weight, wings, neck and chank in the treatments.

The values obtained for liver showed a high significant difference (P<0.05) among the treatments. Treatment 3 had the highest liver weight followed by treatments (2 and 4). Treatment 1 had the least value.

Increase in liver weight suggest that the liver must have been involved in high metabolic activities of proteins, carbohydrates and lipids.

Table 8: Effect of Chaya Leaf Extract on Carcass Characteristics and Organ Weight of Broiler Chicken

Parameters (g)	T_1(0g)	T_2(20g)	T_3(40g)	T_4(60g)
Dressing weight (g)	2475.16 ±27.51^c	2647.16 ±4.20^b	2770.50 ±40.49^a	2509.16 ±13.58^c
Drumstick (g)7	23.40 ±0.24	23.49 ±0.21	21.33±1.01	23.55.±0.01
Breast weight (g)	17.38 ±2.84	18.37±2.89	16.57±0.22	15.11±0.09
Back weight (g)	19.99±2.42	19.19±2.19	21.00±1.17	19.78±1.09
Thigh weight (g)	16.18±2.62^b	20.41±1.6^a	22.42±1.51^a	22.91±0.17^a
Wing (g)	13.51±2.62	10.83±2.02	10.53±0.19	11.72±0.60
Neck (g)	3.76±0.15	3.92±0.18	4.44±0.79	4.15±0.10
Shank weight	3.85±0.13	3.74±0.24	3.45±0.05	3.67±0.10
Liver (g)	42.03±0.29^b	46.50±0.29^{ab}	50.00±0.29^a	44.57±0.23^b
Heart (g)	13.67±0.17^b	14.75±0.14^b	15.50±0.12^a	14.65±0.92^b
Spleen (g)	3.27^b±0.15	3.28±0.06	3.73±0.01	3.45±0.29

^{a,b,c} Means within each row bearing different superscript differ significantly (P<0.05).

The result showed that the heart followed the same trend with the liver. The heart is a muscular organ that pumps blood throughout the body of broiler birds. Increase in heart weight suggest the ability of the broiler chicken in the dietary groups (2,3 and 4) to maintain normal function of the heart for proper blood circulation.

CONCLUSION

Chaya leaf aqueous extract has the potential to enhance performance, carcass characteristics and health status of broiler chicken. It is the bioactive components of chaya leaf as well as its phytobioactivity profile that are responsible for its high nutritional and medicinal benefits.

REFERENCES

Adamu, H.M., Paidayi Gabriel B. and Ushie, O.A. (2020). The proximate composition and Anti-nutritive content of Cnidoscolis aconitifolius leavvs. *International Journal of Biochemistry Research and Review.*29 (8): 65-73.

Awoyinka, O.A, Balogun, I.O and Ogunowo, A.A. (2007). Phytochemical screening and in vitro Bioactivity of cnidoscolus (Euphorbiaceae). *Journal of Medicinal Plants and Natural Product.* 1, 15-19.

Adaramoye, OA, Aluko, A and Oyagbemi, A. (2011). Cnidoscolus seconitifolius leaf extract protects against hepatic damage induced by chronic ethanol administration in wsitar rats. Alcohol and Alcoholism 46(4): 451-458

Akin-Osanaiye, B. C., Adeniran, O. I. and Aderemi, A. S. (2015). Auspicious Antimicrobial Potentials of Ethanol Extracts of Stem and Root of Cnidoscolus Aconitifolius. *International Journal of Medicinal plants and natural products*. 1(1) 15-19.

Alikwe, P.E.N. and Owen, O.J. (2014). Evaluation of the chemical and phitochemical constituents of alchornea cordifolia leaf meal as potential feed for monogatric. *International Journal of Pharmaceutics and Drug Analysis* 360-368. Arntz, 2(4): 360-363.

Antia, S. Akpan, E.J. Okon, P.A and Umoren, I.U. (2006). Nutritive and antinutrive evaluation of sweet potatoes (Ipome abatata) leaves. *Pakistan Journal of Nutrition*. 5(2): 66-168.

Donkoh, A, Atuahene, C.G, Poku-Prempeh, VB, and Twum, I.G (1999). The nutritive value of chaya leaf meal (*cnidoscolus acontitolius* (mill) Jonston): studies wth broiler chickens, Annual feed science and Technology, 77:163-172.

Elagibi, H.A.A, Elaming, W.I.A, Elamin, K.M and Malik, H.E.E. (2013). Effect of dietary garlic (Allium sativum) supplementation as feed additive on broiler performance and blood. *Journal of Animal Science Advances*, 3(2), 58-64.

Grashorn, M.A. (2010). Use of phytobiotics in broiler nutrition – an alternative to infeed artibiotics? Journal of Annual and feed science 19:338-347.https://doi.org//doi.org//10.22358/jofs/66297/2010.

Ivan Moises, S. H., Carla Patricia, B. A., Omar Ricards, T. G. and Eduardo, P. (2017). Nutraceutial Potential of Cnidoscolus aconitifolius. Arc Journal of nutrition and growth, 3(2) 6.1-(1).

Iwuji Samuel, Nwafor Arthur, Eqwurugwu and Chikezie Henrietta (2014). Antihyperglycaenic efficacy of Cnidoscolus aconitifolius compared with Glibenclamide in Alloxan-induced diabetic wistar rats. *International Research Journal of Medical Sciences.*2 (3): 1-4.

Jannatara, K., Teck, C. L., Hool, L. F., Henny A. and Kabiriel, I. K. (2020). Growth Performance, Cytokine Expression and Immune Responses of Broiler Chickens Fed a Dietary Palm Oil and Sunflower Oil Blend Supplemented with L-Arginine and varying concentrations of vitamin E. Frontiers in Vet. Science. 7: 619.

Jayashree, K.V and Gopukumar, S.T (2018). Estimation of Qualitative and Quantitative Phytochemical screening of cridoscolus aconitifolius latex. Journal of Applied Science and Computatious. 5(10).1639.

Kailas, P. (2008). Serum biochemical changes in rabbits on a regular diet with and without flax lignin complex following a high-cholesterol diet. *International Journal of Angiology,* 17(1): Pp 4-7.

Kim, H.Y. Moon, B.H. Lee H.J. and Chio, D.H. (2004). Flavonoids, glycosides from the leaves of Eucommia ulmoides with glycation inhibitory activity. *Journal Ethnophormacol,* 93: 227-230.

Kutathuran, P.R, Narayanan, n, Childambarana N. and Jegan, N. (2014). Phytochemical Analysis of Leaf Extract of Cnidoscolus chaya amansa. International *Journal of phamacomosy and phytochemical Research,*6 (4): 741-745.

Marcos Barcellos Café, Fabricio Rereira Rinaldi, Hugo Ribeiro Morcais, Mara Regina Bueno de mathos Nascimento, Antonio Vicente Mundim. Christiane ferrrira prazeros marchini (2012) Biochemical bold larameter of Broilers at Different ages under Thermonential Environment. World's Poultry Science Journal, 1;142-146.

Mordi J.C. and Akanji, M.A. (2012). Phytochemical screening of the dried leaf extract of Cnidoscolus aconitifolius and associated changes in liver enzymes induced by its administration in wistar rats. *Curr. Res. Journal of Biological Sciences.* 4 (2): 153-158.

Ndukwu, E. E, Owen, O. J. and Gunn, Hlt (2018). Phytobioactive Potentials of Aqueous Extract of *Cnidoscolus aconitifolius* on Performance, Health and Grwoth Responses of weaner Rabbits, Delta Agriculturists *Journal; Faculty of Agriculture, Rivers State University*. 10 (1): 107-115.

Oni, O. O. Alabi, J. O, Ademwole, M. A. and Adegbenjo, A.A. (2018). Effect of phytobiotics (Mixture of Garlic, Ginger and chaya leaf) on growth performance, Haemotological and biochemical indices of pullets chicks. *National Agricultural and Food Centre, Slovok Journal of Anil*-SC. 5:69-78.

Piotrowska, A, Burlikowska, K and Szymeczko, R. (2011). Changes In blood chemistry in broiler chickens during the fattening period Folia Biologica (Krakow), 59: 183-187. Dol:10.3409/fb59_3.4.183-187.

Victor, M., Abbey, P. A., Joseph, Y., Jonathan, Z., Bobai, YK and Maria, O. (2016). Underexploited tropical plant with promising economic value and he window of opportunities for researchers. Cnidoscolus aconitifolius. American Journal of Food Science and Nutrition Research. 3(6): 177-187.

Zarmai, I.T, Babtunde, M.M. and Abdullahi, S.A. (2017). Proximate constituents of raw and blanced leaves of chaya (cnridoscolus chayamansa) *African Journal of Food Science and Technology.* 8 (5):074-080.

RURAL CREDIT SOURCES AND CONSTRAINTS IN SOUTH-SOUTH NIGERIA: EVIDENCE FROM CASSAVA-BASED FARM HOUSEHOLDS

Edaba, M.I.E., Onoja, A.O. and Elum, Z.A
Department of Agricultural Economics and Agribusiness Management
University of Port Harcourt, Choba, Port Harcourt, Nigeria
E-mail: michaeledaba@yahoo.com

Abstract

This study investigated rural credit sources and constraints in South-South Nigeria with evidence from cassava-based farm households. It ascertained the amount and sources of credit accessed, analyzed the factors limiting credit access, and identified the possible ways of improving credit access. Primary data comprising 284 cassava-based farmers from Akwa Ibom, Rivers, and Bayelsa States, South-South Nigeria were investigated by utilizing the process of multiple-stage random sampling. The data were analyzed using factor analysis and descriptive statistical methods. Results revealed that most of the farmers obtained credit through informal sources, with personal savings (54.9 percent) appearing dominant while the majority of the formal credit category of farmers obtained credit through cooperative societies (32.4 percent). In addition, the least source of credit among the farmers in the area was found to be banks of industry (0.7 percent) and mobile money operators (7.5 percent). Among the constraints found to limit credit access to farmers, the findings identified factor 1, accessibility and physical factors loading high with lack of collateral (0.801), lack of mobile network (0.783), effects of oil bunkering and spillage (0.782), inadequate insurance (0.777) and poor loan repayment history (0.751), in an order of descending influence. To improve access to credit, 98 percent of the respondents identified the need to reduce interest rates, 86.6 percent indicated that financial institutions should be located in rural areas and 84.5 suggested the need to provide collateral-free loans to farmers. It is strongly recommended that the government take steps to reduce the interest rates on farm credit so that farmers may be attracted to apply for formal credit. The processes of loan acquisition should be examined and made simpler. Finally, farmers' preferences and requirements should be taken into consideration when developing policy initiatives to increase access to farm financing.

Keywords: Credit, Rural, Agriculture.

Introduction

The goal of producing enough food to feed our growing population is becoming increasingly challenging due to a number of factors. One of the main challenges is the lack of access to credit and other financial services for small-scale farmers. Studies in Nigeria have shown that many rural farmers are unable to achieve maximum output in their farm business due to numerous constraints, such as lack of collateral, poor information dissemination, high interest rates, and the inability to access funding agents. Additionally, inflation has led to higher-priced farm equipment, and there are fewer arable lands available. All of these issues make it difficult for farmers to increase their productivity and reduce poverty. Access to credit and other financial services have been seen as a promising way for small-scale farmers to reduce poverty and increase farm productivity but Osabohien *et al*., (2020) observed that our hope of producing sufficient food to feed the exploding global population appears to be challenging because, among other things, there are less arable lands, higher-priced farm equipment because of inflation, fewer farmers have access to finance, and rural-urban migration. Similar studies in Nigeria (Adeleye *et al.,* 2020; Osabohien *et al.,* 2020; Balana, and Oyeyemi, (2021); Mallum (2016; Balana, and Oyeyemi, (2021); have shown evidence that many rural farmers are unable to achieve maximum output in their farm business due to numerous constraints such as lack of collateral, poor information dissemination, high-interest rates, and rural farmers' inability to access funding agents.

In an effort to increase agricultural financing in light of the potential significance of agricultural credit markets in fostering general economic growth and development, the Nigerian government implemented a number of programs, including the Agricultural Transformation Agenda (ATA), Anchor Borrowers Scheme, Accelerated Agricultural Development Programme (AADS), Commercial Agriculture Credit Scheme (CACS), and Agricultural Credit Guarantee Scheme Fund (ACGSF), among others (Osabohien *et al.,* 2020). Many states in the country have also assisted the federal government by implementing financial schemes to spur growth in the agricultural sector where they have a competitive advantage (Nevin et al., 2019). The National Bureau of Statistics reports that in 2016 and 2017, respectively, loans to agriculture accounted for 3.26% and 3.36% of all credit to the private sector. Although the government has undertaken the aforementioned programs in an effort to boost production, the availability of finance for agriculture is still limited (Balana and Oyeyemi, 2021).

The supply of credit is now acknowledged as a crucial instrument for increasing the incomes of rural communities, particularly through mobilizing resources for more productive uses, according to Ukwuaba et al. (2020). Scholarly research has maintained that credit may improve recipients' living situations by raising their agricultural productivity to increase income as well as their sense of self-worth and well-being. For instance, Ogbuabor and Nwosu (2017) considered farm credit to be a crucial element of the agricultural business sector in Nigeria, capable of significantly increasing farm output, farm family income, and helping the poor accumulate wealth to engage in farming. It is a tool that has the potential to modernize conventional agriculture while also opening up new job possibilities. Credit is therefore a key element that could address productivity issues and reduce extreme poverty, supporting the creation of self-employment in the rural sector for investment in working capital. This is also one of the main strategies for alleviating poverty in the majority of developing countries (The World Bank, 2020).

It is interesting to note that in many developing nations, both formal and informal sources are used for rural agriculture financing. Formal financial entities, such as legally chartered banks, are the major credit lenders. However, borrowers and depositors must follow prescribed application procedures under official sources in order to get credit from credit institutions. The Central Bank of Nigeria (CBN) governs and oversees these institutions, providing loans, savings, insurance, and other financial services and products. Informal lenders, on the other hand, include friends, family members, and money lenders in rural regions. These lenders are essential in helping farmers access short-term repayable funds for their farm operations. Farmers usually get modest, quickly repayable loans from these unofficial lenders in the form of cash or crop supplies. It is worth noting that these lenders' operations are usually not monitored by any regulatory agency, and less stringent screening mechanisms are employed in their daily operations.

Farmers in Nigeria's agricultural sector confront a number of challenges when trying to get loans to expand their businesses. Distance to lending institutions, a lack of financial inclusion, greater transaction costs, poor literacy rates, and a lack of collateral security are a few of the issues that have been shown to negatively impact rural regions' access to credit (Olomola and Gyimah, 2017). Others include the absence of guarantors, discrimination based on gender, a delay in loan approval, racial tensions, bad government policies, etc. For instance, farmers in remote areas might not have access to enough information about loan providers, the requirements for applying for credit, or interest rates. As a result, even if they require credit, they lack the knowledge to do so. This is further compounded by the problem of gender bias, lack of guarantorship, and limited Insurance coverage (Kiros and Meshesha, 2022). Given the significant role of farm credit in the agricultural sector, it is important to evaluate the sources of farm credit as well as the factors that affect its access.

The main aim of this paper was to investigate and assess rural credit sources and constraints in South-South Nigeria: evidence from cassava-based farm households. The specific objectives include:

i. identify the socioeconomic characteristics of Cassava-based farmers;
ii. ascertain the sources of credit to Cassava-based farmers;
iii. determine the constraints to obtaining credit from the available credit sources

Statement of the Problem

According to Abdulgafar *et al.,* (2017), inspite of the huge human and material resources committed to food crop production, the production efficiency of arable crop farmers is still struggling below 60 percent, implying that farmers are not doing things right. One of the major sources of agricultural risk in Nigeria is the poor use of scarce resources, which results in low farm output. The obvious problem of underutilization of resources, as listed by Nzeakor *et al.* (2021), is typically manifested by the adoption and application of low input technologies, limited access to credit, inadequate agricultural extension services, limited knowledge of high input technologies, and inadequate farm management skills. Input scarcity, high cost, long distances to market, intergroup violence, and the impact of climate change on the overall farming culture are additional obstacles. Poor extension service delivery is another. Other issues include how to investigate the numerous aspects that explain efficiency in order to increase the nation's output of food crops.

In addition, because of the characteristics of rural credit markets and lending practices, household access to credit in many rural communities of South-South Nigeria continues to be a challenge. Rural locations are known to have both formal and informal markets. According to Saqib *et al.* (2018), because of market inefficiencies made worse by poor institutional structures, formal lending institutions' supply tends to decline, which means that informal loan sources are likely to predominate in rural areas. Poor and low-income households frequently have restricted access to formal credit because they lack sufficient collateral and hence are unable to borrow based on their income. (Ta *et al*. 2019).

Literature Review

It has been argued in the literature that the main reason behind the poor performance of Africa's agricultural sector, especially Nigeria is because farming is done manually, with the use of crude labour on minimal acreage and low credit facilities (Chisasa and Nakina 2015; Guirkinger and Osabohien *et al*. 2020). Agricultural financing gap arising from credit constraint has been pointed out in extant literature to have a negative impact on agricultural performance (Ojo and Ayanwale 2019; Osabohien *et al*. 2018, 2020). Often, farmer's inaccessibility of farm credit have been known to exert an adverse effect on their ability to purchase the required farm input for sufficient production (Ojo and Ayanwale 2019). Therefore, agricultural transformation is possible if the available sources of farm credit could be easily accessed, as it will help to improve agricultural performance (Osabohien *et al*. 2019). Numerous studies on the subject of agricultural credit access have been conducted (Nwaru, 2004; Muhammad et al., 2013); some have compared the impact of interest rates on access (Ali et al., 2017); others have concentrated on access by particular farmers (Bashir, Mehmood and Hassan 2010); a good number have examined sources of credit (Guirkinger, 2008; Ijioma and Osondu, 2015; Mgbakor, Uzendu and Ndubuisi, 2014); while others have limited access to small-scale farmers (Badiru, 2010; Asogwa, Abu and Ochoche, 2014).

According to Ukwuaba et al., (2020), farmers frequently select a particular credit provider based on ease of access and other considerations. For instance, the further away the credit source is from the farmers, the more likely their access is reduced. This finding demonstrates that the majority of farmers preferred informal sources over official ones. This could most likely be the result of the farmers' lack of cooperative membership, limited farm size, and lack of collaterals. Similarly, Assogba, Kokoye, Yegbemey, Djenontin, Tassou, & YABI, (2017) found that instead of formal or semi-formal sources such as banks or cooperatives, a good proportion of farmers obtain their credit through informal sources like friends and family. This may be due to the bureaucracies and lax requirements often required to access credit from the formal credit institutions.

Ukwuaba et al., (2020) identified some of the constraints to rural credit access to include: lack of collateral, late disbursement of approve loans, and poor awareness of the rules and regulations regarding credit processing from financial institutions. Others constraints include discrepancy between the amount of credit requested and the amount released, as well as the complicated procedures common with formal credit access. Ciaian *et al*. (2012) reported that credit constraints do not only lower agricultural production but also weaken economic growth in secluded rural areas which are not easily accessible. Tang *et al*. (2010) found that rural household savings and spending influenced by credit access. As a result, access to credit, empowers farmer's potential to carry out his budgetary necessities that facilitate to smoothly invest in inputs, implements, and productive investment.

Methodology

Study Area

South-South Nigeria served as the location of the study. The following states are included in the South-South geopolitical region of Nigeria: Akwa Ibom, Bayelsa, Cross River, Delta, Edo, and Rivers States. The South-South zone has an estimated population of 26,551,327 and occupies nearly one-third of Nigeria's total land area. Sheep, goats, and chickens are just a few of the animals that farmers in the area mostly raise, along with other arable food crops. Among the staple foods are cassava, maize, sweet potatoes, yams, plantains, bananas, and vegetable crops grown. The farmers cultivate a variety of crops, including cocoyam, maize, yam, cassava, plantain and vegetables, etc.

Sampling Techniques and Sample Size

Farmers who cultivate cassava crops in the selected States were sampled using a multi-stage sample technique from the specified population. The first step featured the selection of two (2) Local Government Areas (LGA) and the second stage required the selection of two (2) Agricultural Development Programmes (ADPs) zones from each of the Agricultural Zones of the relevant States (Rivers, Akwa Ibom, and Bayelsa). In the third stage, four (4) villages from each LGA were also randomly chosen. Finally, six (6) farmers who grow cassava were randomly chosen from each community based on their access to official or informal credit, for a total of two hundred and eighty-eight (288) respondents. The population of the research consists of all farmers in South-South Nigeria who cultivate the cassava crop. In the 48 communities that were chosen for the study, the ADP office in each State provided a total of 3,850 cassava farmers. The sample size was determined using the sampling frame methodology developed by Krejcie and Morgan and used by Nanjundeswaraswamy and Divakar in the year 2021.

Data Collection

Data for this study was cross-sectional data collected from primary sources. Data was collected from cassava farmers (respondents) during the 2021/2022 cropping season. These connections helped with the pre-testing of the research instruments and offered instructions for creating the research instrument (questionnaire). Using a well-structured questionnaire and a timetable. The primary data was collected from the following variables: socio-economic characteristics of the respondents such as age, sex, household size, educational background, farm experience, farm size, extension contacts, farm input quantities and unit price crops, costs, and benefits, the quantity of yield and market price crops, expenditures, area of land cultivated, access to credit, labour input, loan repayment history etc.

Analytical technique and model specification

Data was analyzed using both descriptive and inferential statistics. Factor analysis (FA) model has been adopted in research by several authors like Ancuta, *et al.,* (2012) reported in usefulness of principal component analysis in agriculture and expressed the factor analysis model as;

$$Z = \alpha_1 X_1 + \alpha_2 X_2 + \cdots + \alpha_n X_n \qquad (1)$$

Where;

α_1 is the coefficient of the component factor

X_1 is the variable

Adewumi, and Yisa (2019) and Unachukwu, and Yisa (2022) also used factor analysis constraints of smallholder arable crop farmers in Kwara State and North Central Nigeria respectively. They stated the model as;

$$Y_1 = \alpha_{11} X_1 + \alpha_{12} X_2 + \cdots + \alpha_{1n} X_n \qquad (2)$$

$$Y_2 = \alpha_{21} X_1 + \alpha_{22} X_2 + \cdots + \alpha_{2n} X_n$$

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$Y_n = \alpha_{n1}X_1 + \alpha_{n2}X_2 + \cdots + \alpha_{nn}X_{nn}$; Where:

$Y_1 - Yn$ are the observed constraint variables

$\alpha_1 - \alpha_n$ are the constraint loading coefficients

$X1 - Xn$ are unobserved

Results and Discussions

Table 1: sources of credit for cassava-based farms

Sources	Type	Frequency	Percentage
Formal	Commercial Banks	18	11.9
	Cooperative Society	49	32.4
	Bank of Agriculture	13	8.6
	Bank of Industry	1	0.7
	CBN NIRSAL	42	27.8
	Microfinance Banks	28	18.5
		151	**100**
Informal	Friends	21	15.8
	Relatives	17	12.8
	Personal savings	73	54.9
	Money lenders	12	9.0
	Mobile money	10	7.5
	Total	**133**	**100**

Source: field survey, 2023.

Results from Table 1 divulge the common sources of credit for cassava-based farmers in the study area. It showed that rural farmers obtained most of their credits from both prescribed formal sources and non-formal sources. The former sources include cooperative societies, 32.4 percent; Nigeria Incentives-Based Sharing Agricultural Lending System (NIRSAL, funded by the Central Bank of Nigeria) 27.8 percent; Microfinance banks, 18.5 percent; Commercial banks, 11.9 percent and Bank of Agriculture, 8.6 percent; the least under formal sources is bank of Industry, 0.7 percent. Other credit sources recognized were mainly from informal sources. Results from the survey reveal that the most dominant informal source of credit in the area were: personal savings, 54.9 percent; friends, 15.8 percent; relatives, 12.8 percent; moneylenders, 9.0 percent; The Federal Government initiated the Incentives Banking Scheme to enable the free flow of funds and to subsidize the cost of small-scale farming amongst young school leavers in the country.

In all the three states sampled, a reasonable number of the cassava-based farmers revealed that they received incentives in the form of fertilizers and pesticides worth between two hundred to three hundred thousand nairas (N200,000-300,000) last year from the Federal Government Ministry of Agriculture and natural resources under the Cassava Growers Association of the country. They added that ''the support was realized through the Nigeria Incentives-Based Sharing System for Agricultural Lending (NIRSAL, funded by the Central Bank of Nigeria) at a 4 percent interest rate.'' Experience in rural development reveals that efforts at improving the economic base of the rural area are usually flawed by scarcity and restrictive access to funds (Famogbiele, 2013). Ekwere et al. (2020) noted that the need became necessary because farm credit is a crucial tool for ensuring sustainable efficiency in agricultural production as well as enhancing agricultural development, providing agricultural credit to farmers was urgent and required global attention even in well-developed countries of the world. Farmers will be able to buy modern agricultural equipment, and access high-quality seeds, fertilizers, better cuttings, and labour due to the supply of adequate credit, all of which help farmers plan for their farm production activities

Table 2: Factors limiting rural credit access by cassava-based farmers

Variables	***Component Factors**				
	1	**2**	**3**	**4**	**Communality**
Accessibility and physical factors					
Lack of collateral	0.801				0.858
Lack of mobile networks	0.783				0.787
Crude oil spillage	0.782				0.790
Inadequate insurance	0.777				0.778
poor loan repayment history	0.751				0.730
Sentiment and tribalism	0.558				0.932
Poor and govt. policies	0.526				0.922
Religious and lender factors					

Lack of banks in locality		0.819			0.803
**Small approved loan		0.818		0.320	0.841
Lack of guarantorship		0.708			0.620
Religious beliefs		0.682			0.712
Lack of awareness		0.678			0.636
**Late Approval of loans	0.478	0.531			0.631
Institutional and security factors					
Illiteracy			0.873		0.958
Incidence of violence			0.873		0.958
No bank account			0.868		0.940
**Gender bias		0.427	-0.524		0.952
**Crop failure-climate effects		0.376	-0.502		0.947
Delay in disbursement				0.803	0.669
Bureaucratic and farm-related					
Small scale farming				0.711	0.580
Delay in loan approval				0.694	0.698
**High interest rate	0.438			0.554	0.636
Bureaucracies				0.415	0.496
Eigenvalues	**6.921**	**3.489**	**2.379**	**1.899**	
Percentage of Variance	**30.091**	**15.171**	**10.342**	**8.259**	
Kaiser-Meyer-Olkin (KMO)	**0.803**				
Bartlett's Test of Sphericity	**0.001**				

***Factor 1 = Accessibility and physical factors; Factor 2 = Religious and lender factors; Factor 3 = Institutional and security factors; and Factor 4 = Bureaucratic and farm-related factors.**
** Signifies constraints variables that loaded in more than one component factors.

The constraints limiting rural credit access were analyzed and shown in Table 2 using varimax rotation criterion Kaiserm; the sampling adequacy of the data was investigated using the Kaiser-Meyer-Olkin (KMO) (Kaiser, 1970 as cited in Taherdoost, *et al,* 2014). The KMO ranges from 0 to 1, and 0.803 was obtained which shows that the data were considered suitable for factor analysis (FA) as stated that a Kaiser-Meyer-Olkin correlation value above 0.60 is considered adequate for investigating the FA output. Bartlett's test of sphericity concerns the significance at 1% level, this shows the accuracy and the suitability of the data and the result. The eigenvalues were adequate as seen in Table 2 were above one (1) as noted by Taherdoost *et al* (2014) who stated that eigenvalues of above 0ne (1) should be considered in interpretation. Hence, the variables under the four (4) component factors were considered for adequate interpretation.

Factor 1 (Accessibility and physical factors): The constraints that loaded high under factor one include lack of collateral (0.801), lack of mobile networks (0.783), crude oil spillage (0.78), inadequate insurance (0.777), poor loan repayment history (0.751), sentiment and tribalism (0.558), poor government policies (0.526). From the results of factor 1, lack of collateral security loading at 0.801 constitutes a very serious burden and hurdle to the rural farmers, in terms of credit constraints categorization, meaning that a certain farmer's ability to obtain credit is restricted or refused as a result of insufficient collateral. Farmers' access to credit facilities in the study region is significantly impacted by the need that they furnish collateral for loans in the majority of situations.

Typically, a variety of real estate assets are utilized as collateral, including commercial real estate, agricultural land, landlord guarantees, neighbor or family guarantees, etc.

In Nigeria, land is a basic form of collateral requested (Amurtiya *et al.,* 2018), to the extent that if not available or inadequate, the chances of getting credit remain slim especially. Under the African settings, land is a sacred property that is required to be passed from generation to generation. Hence, most farmers are unwilling to pledge their landed property as collateral security in exchange for bank loans (Gadnakis, 2019). According to Li *et al.* (2018), adequate collateral was crucial in obtaining loans from formal credit organizations in rural areas. Consequently, most farmers bound their lands for collateral in the bank and other financial institutions with a negligible share. This is further compounding the predicament of farmers by adding more burdens to the challenges confronting farmers in rural areas. It is also clear from the findings that most of our rural communities in South-South Nigeria lack adequate mobile network coverage, and it is already constituting a major challenge to farmer's access to credit facilities. This result agrees with Balana and Oyeyemi (2021) who noted that inadequate access to the internet (ICT) constraints smallholder farmers in Nigeria's access to agricultural credit.

Results from factor 1 also revealed a very high loading (0.782) for crude oil spillage, indicating that oil spillage is posing major constraints to farmers in the area. Edaba and Brown (2021) reported that oil spillage has degraded and undermined the local economies of Oil Producing Communities in Southern Nigeria leading to occupational disorientation as well as the displacement of the rural poor from their already polluted farmlands, leading to exacerbation of poverty. In addition, inadequate insurance coverage, poor loan repayment history, sentiment and tribalism during the loan application process, and poor government policies were identified as barriers limiting rural credit access amongst cassava-based farmers.

Under **factor 2 (religious and lender factors),** the variables that constitute as constraints to formal credit access include: Lack of banks in locality (0.819), loan approved too small loaded under factor 2 (0.818), and under factor 4 (0.320) but had a higher loading under factor 2, lack of guarantorship (0.708), religious beliefs (0.682), lack of awareness of loan opportunities (0.678), and late approval of loans which loaded under factor 2 (0.531) and under factor 1 (0.478) but loaded higher under factor 2.

From the result, the lack of banks in local or rural areas was identified as a key factor that hinders cassava farmers from accessing credit from banks. According to Danso-Abbeam and Baiyegunhi (2017), there are important socio-demographic variances among regions, which may influence farmers' response to access and use of farm inputs such as farm credit. High transaction costs of credit and vulnerability of the location to insecurity, weak infrastructure, and the devastating challenge of flooding in the study area could be plausible reasons for smallholder cassava farmers in the area being credit-constrained. Conversely, the negative relationship with location, and limited banks in the rural areas implies farmers in urban areas are likely to apply for more loans than their counterparts in rural areas. The primary factor contributing to the trend in this result is the concentration of branches of financial institutions in the nation's largest towns and cities, including those of the Bank of Agriculture, NIRSAL (CBN) Microfinance Bank, and commercial banks. This further suggests that, unless urgent measures are taken to establish financial institutions in rural areas, the federal government of Nigeria's intended cashless policy may not be fully implemented at the proper time. This result further agrees with Adewumi *et al* (2019) who reported that the challenge of no bank branches in many rural areas of Nigeria for small-scale farmers is a major setback to agricultural productivity.

In addition, lack of guarantorship is also identified as a major constraint to cassava farmer's timely access to adequate credit needed for the improvement of cassava production. This outcome is expected because rural dwellers in Nigeria live below the poverty threshold and may lack guarantors to stand in as sorties during the process of loan application (Taremwa *et al.,* 2022)

Under **factor 3 (institutional and security factors)** the variables include illiteracy (0.873), the incidence of violence (0.873), no bank account (0.868), gender bias loaded under factor 3 (-0.524), and under factor 2 (0.478) but loaded higher under factor 2; crop failure due to climate effects also loaded under factor 3 (-0.502) and under factor 2 (0.376) but loaded high under factor 2. In particular, illiteracy is shown to have a very high loading (0.873) amongst farmers in the area. This means that a given level of education will have a log of odds of accessing credit. The interpretation is that an increase in additional years spent in school will correspondingly increase farmer's access to farm credit and vice versa. In a similar view, Okezie (2010) reported 47 percent alarming levels of illiteracy amongst rural-based farmers in Nigeria. According to Amaechi (2007), formal education improves the producers' managerial abilities of record keeping, logical decision-making, cost reduction, and opportunity maximization. As a result, it is anticipated that receiving a formal education would be favorably related to financial literacy, which is a need for being effective when applying for jobs and using credit. Regardless of the action, violence is using force to cause bodily or psychological harm and pain to another person (Evoh, 2009). According to the findings for factor 3, violence loaded quite high (0.873). The majority of the dreadful violence in Nigeria, according to Evoh (2009), occurs in South-South Nigeria, especially in the communities shared by peasant farmlands and crude oil fields. These areas are well known to have been drastically altered with little to no recompense to anybody. With the ensuing effects of youth unrest, poor agricultural output, and poverty as well as the apparent movement of corporate offices of multinational oil firms to other regions of the country, this has exacerbated tension in the study area.

Lack of bank accounts was another significant barrier to rural cassava farmers' access to credit under factor 3 (loading at 0.868). *Sebatta et al.,* (2014) claim that having a savings account with a commercial bank increases the probability that one would be approved for loans because it lessens the knowledge gap between the banker and the farmer. The ability to monitor and evaluate the account activity and transactions of account holders may also help bank authorities determine a future loan applicant's credit score. Additionally, the existence of a bank account gives the bank's management confidence in the likelihood of loan payback by the account user.

Under **factor 4 (bureaucratic and farm-related factors)**, delay in payment of approved loans (0.803), small-scale farming (0.711), delay in loan approval (0.694), high-interest rates loaded under factor 4 (0.554) and under factor 1 (0.438) but loaded high under factor 4, while bureaucracies loading at (0.415) were found to influence credit access. From the results, those farmers who could access credit were also facing the challenge of delay in payment of approved. Loans for cassava production. This result agrees with Unachukwu *et al.* (2022) who reported that poor timing of loan disbursement to farmers in North Central Nigeria constraints farmers' access and utilization of agricultural loans.

Consistent with the report of Isaga (2018), the results of this study reveal a relationship between farm holdings and access to farm credit. In a similar finding, Taremwa, (2022) observed that smallholder farmers who cultivate on farmlands below 0.1 ha were unlikely to have access to formal agricultural credit. This finding is connected to some of the fundamental requirements for obtaining loans from certain financial organizations. According to Amurtiya *et al.,* (2018), land is still one of the most frequently requested types of collateral. This finding is related to previous reports that showed some of the fundamental requirements for obtaining loans from certain financial institutions, particularly if credit risks need to be reduced or even avoided. This is due to the fact that farmers with smaller holdings will have low production, which will leave them with little money to pay back agricultural loans, which limits their chances of being approved for farm credit facilities from any financial.

Similarly, based on the findings, interest rates seem to prevent farmers in the research region from using lending facilities. Even when all credit lending terms and standards are met, interest rates might cause hesitation in getting the agricultural credit sum. High-interest rates might make it difficult for small-scale farmers to get finance. More so the farmers in the context of South-South Nigeria, whose land sizes are found to be relatively below 1 ha. This result agrees with Adebayo *et.,* (2017), Owueye and Toluwase (2020), and Unachukwu, *et al.,* (2022) who confirmed that high-interest rates and lack of banks in rural areas are among the major constraints to adequate access and utilization of agricultural loans from formal funding sources (such as banks).

Conclusion and Recommendations

Farm production has been shown to be significantly influenced by agricultural financing. This study uses information from Nigerian farm households based on the cassava crop to investigate rural credit sources and constraints in South-South Nigeria. Our data show that both formal and informal sources were often used for agricultural loans in the research region. The most prevalent informal sources of farm credit were found to be personal savings (54.9%), friends (15.8%), relatives (12.8%), and moneylenders (9%) while cooperative societies (32.4%), the Nigeria Incentives-Based Sharing Agricultural Lending System (NIRSAL, funded by the Central Bank of Nigeria), 27.8%, microfinance banks (18.5%), and commercial banks were the most prevalent sources of formal credit in the region. Among the constraints found to limit credit access to cassava-based farmers in the study area, the findings identified factor 1, accessibility and physical factors loading high with lack of collateral (0.801), lack of mobile network (0.783), effects of oil bunkering and spillage (0.782), inadequate insurance (0.777) and poor loan repayment history (0.751).

Based on these findings, we strongly believe that it is crucial for the government and all stakeholders to take action to reduce the interest rates and bureaucracies associated with loan applications. This will encourage farmers to apply for credit facilities, ultimately leading to increased farm productivity, output, and food security for the nation. It is also important to educate farmers on how to seek financing and manage it properly once they receive it. When creating new legislative measures to broaden access to agricultural financing, it is essential to take into account farmers' preferences and needs. By implementing these measures, we can ensure a thriving agricultural industry and a more secure future for all.

References

Abdulgafar, Xu, Yu, & Wang (2017). Comparative study on factors influencing rice yield in Niger State of Nigeria and Hainan of China. *International Journal of Agricultural and Food Research,* 6(1), 15-25.

Adeleye, N., Osabuohien, E. & Asongu, S. (2020) Agro-industrialisation and financial intermediation in Nigeria. African Journal of Economic and Management Studies. Volume 11 Issue 3

Adewumi, A., Tanko, L., Ibrahim, F.D. & Yisa, E.S. (2019). Principal component analysis of production constraints of smallholder arable crop farmers in Kwara State, Nigeria. Retrieved from: https://www.researchgate.net/publication/340635254

Ali, E. & Awade, N.E. (2017). Credit constraints and soybean farmer's welfare in subsistence agriculture in Togo. Heliyon 5, 1550.

Amurtiya M., Yuniyus G., Polycarp M. & Zubairu A. (2018). Analysis of rural farm households' access to formal agricultural credit in Yola south local government area, Adamawa state, Nigeria. Acta Univ. Agric. ET Silvic. Mendelianae Brun., 66 (4), 947-954

Ancuta, S., Ancuta, R., Ioana, P., Anamaria, V., & Cioban. A. (2012). Usefulness of Principal Components Analysis in Agriculture. Bulletin of University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca. *Horticulture* 69(2):1843-5394

Assogba, P. N., Kokoye, S. E., Yegbemey, R. N., Djenontin, J. A., Tassou, Z., , J., & YABI, J. A. (2017). Determinants of credit access by smallholder farmers in North-East Benin. *Journal of Development and Agricultural Economics,* 9(8), 210-216

Assogba, P. N., Kokoye, S. E., Yegbemey, R. N., Djenontin, J. A., Tassou, Z., Pardoe, J., & Yabi, J. A. (2017). Determinants of credit access by smallholder farmers in North-East Benin. Journal of Development and Agricultural Economics, 9(8), 210-216.

Balana, B.B. & Oyeyemi, M.A. (2021). Credit constraints and adoption of agricultural technologies in developing countriPardoees? Evidence from Nigeria by Paper presented at the International Conference of Agricultural Economits (ICAE 2021), August 17-31, Online.

Bashir, M. K., Mehmood, Y., & Hassan, S. (2010). Impact of agricultural credit on productivity of wheat crop: Evidence from Lahore, Punjab, Pakistan. Pakistan Journal of Agricultural Science, 47(4), 405-409. CARTER, M. R. (1989). The impact of credit on peasant productivity and differentiation in Nicaragua. *Journal of Development Economics*, 31(1), 13-36

Chisasa, J., & D. Nakina. 2015. "Bank Credit and AgriculturalOutput in South Africa: Cointegration, Short Run Dynamicsand Causality." Journal of Applied Business Research(JABR) 31 (2): 489–500

Ciaian, P., Fałkowski, J. & Kancs, D. (2012). Access to credit, factor allocation and farm productivity: evidence from the CEE transition economies. *Agric. Finance Rev*. 72 (1), 22–47.

Danso-Abbeam G, & Baiyegunhi LJS (2017) Adoption of agrochemical management practices among smallholder cocoa farmers in Ghana. Afr J Sci Technol Innov Dev 9(6):717–728

Edaba, M.I.E. & Brown, P. (2021). Effects of Crude Oil Spillage on Farm Income and Livelihoods of Rural Farm Households in Bayelsa State, Nigeria." *Agricultural Economics and Extension Research Studies* (AGEERS) Vol. 9, No.1.

Ekwere, G. & Edem, I. (2014). Evaluation of agricultural credit facility in agricultural production and rural development. Glob. J. Hum. Soc. Sci. Res.
enterprises: a double hurdle approach. *Ghana J. Dev. Stud.* 2017; 14(1):146–165

Evoh, C.J. (2009). "Green Crimes, Petro-violence and the Tragedy of Oil: The Case of the Niger-Delta in Nigeria". Inspire Journal of law, *Politics and Societies,* 4(1), 11-19.

Farmers in Nigeria. IFPRI Discussion Paper 01403. Washington, DC.

Gadanakis, Y (2019) it sources, access and factors influencing credit demand among rural livestock farmers in Nigeria Article in Agricultural Finance Review · October 2019.

Guirkinger, C., & S. R. Boucher. 2008. “Credit Constraints andProductivity in Peruvian Agriculture.” AgriculturalEconomics 39 (3): 295–308.

Ijioma, C. J. & Osondu, C. K. (2015). Agricultural credit sources and determinants of credit acquisition by farmers in Idemili Local Government Area of Anambra State. Journal of Agricultural Science and Technology, 5(2015), 34-43

Isaga N. (2018). Access to bank credit by smallholder farmers in Tanzania: A case study. *Afrika Focus,* 31 (1), 241-256

Kiro, S.s & Meshesha, G.B. (2022) Factors affecting farmers' access to formal financial credit in Basona Worana District, North Showa Zone, Amhara Regional State, Ethiopia, Cogent Economics & Finance, 10(1)

Mallum A. (2016). A Review of Agricultural Finance Policy Development in Nigeria). 26(1) University of Maiduguri Annals of Borno.

Mallick, L.., Das, P.K., & Pradhan, K.C. (2012) Impact of educational expenditure on economic growth in major Asian countries: Evidence from econometric analysis, *Theoretical and Applied Economics,* 23(2), 173-186.

Matthew O.A., Osabohien R., Ogunlusi T.O., & Edafe O (2019). Agriculture and social protection for poverty reduction in ECOWAS. *Cogent Arts Human.* 2019; 6:1682107.

Mgbakor, M. N., Uzendu, P. O. & Ndubuisi, D. O. (2014). Sources of agricultural credit to small scale farmers in Ezeagu Local Government Area of Enugu State Nigeria. *Journal of Agricultural and Veterinary Science,* 7(8), 11-8

Nanjundeswaraswamy, T.S. & Divakar, S. (2021) Determination of sample size and sampling methods in applied research. *Proceedings on Engineering Sciences*. 3(1) (2021), 25-32.

National Bureau of Statistics (NBS). 2018. Non-Performing Loans - Selected Banking Sector Data: Sectorial Breakdown of Credit, ePayment Channels and Staff Strength (Q4 2018) Abuja, Nigeria: National Bureau of Statistics

National Bureau of Statistics, Abuja, Nigeria (2018). Sectorial Breakdown of Credit, E-Payment Channels and Staff Strength, NPC, Abuja

Nevin, A.S., Oyaniran, T. & Onomia, O. (2019). Feeding 398 million People in Africa's Largest Economy by 2050 Food Security Challenges and Agricultural Innovation PricewaterhouseCoopers (PWC) Limited

Nwaru J. C. (2004). Rural credit markets and resource use in arable crop production in Imo State, Nigeria. Unpublished Ph.D Dissertation submitted to the Department of Agricultural Economics, Michael Okpara University of Agriculture, Umudike, Nigeria.

Nzeakor, F. C. & Ume, S. I. (2021). Analysis of Profitability and Adoption of Cassava Technology among Adopters and Non-Adopter in Abia State, Nigeria. *AKSU Journal of Agriculture and Food Sciences* 5(3): 98-116.

Odutola Odukoya, A. (2020). Political Economy of Agricultural Commercialization in Nigeria. APRA working paper 29. UK: Future Agricultures Consortium

Ojo, M. P., & A,B Ayanwale. 2019. “Estimating Farm-Level Financing Gap: A Technical Efficiency Approach.”*Agricultural Finance Review* 79 (2): 74–191.

Okojie, C., Monye-Emina, A., Eghafona, K., Osaghae, G. and Ehiakhamen, J.O. (2010). Institutional Environment and Access to Microfinance by Self-Employed Women in the Rural Areas of Edo State NSSPBrief No. 14 International Food Policy Research Institute, Washington. DC.

Olomola, A.S. & K. Gyimah-Brempong. 2014. Loan demand and rationing among small-scale

Osabohien R., Osabuohien E., Ohalete E. (2019). Agricultural sector performance, institutional framework and food security in Nigeria. *Bio base Appl. Econ.* 8(2):161–178.

Osabohien R., Osuagwu E., Osabuohien E., Ekhator-Mobayode U.E., Matthew O., & Gershon O. (2020). Household access to agricultural credit and agricultural production in Nigeria: a propensity score matching model. *S. Afr. J. Econ. Manag. Sci;* 22. (1): a2688.

Saqib, S.; Kuwornu, J.K.M.; Panezia, S.; & Ali, U. (2018). Factors determining subsistence farmers’ access to agricultural credit in flood-prone areas of Pakistan. *Kasetsart J. Soc. Sci*., 39, 262–268.

Sebatta, C.; Wamulume, M. & Mwansakilwa, C (2014). Determinants of smallholder farmers’ access to agricultural finance in Zambia. J. Agric. Sci. 6, 63.

Taherdoost, H., Sahibuddin, S. & Jalaliyoon, N. (2014). Exploratory factor analysis; concepts and theory. *Advances in Applied and Pure Mathematics*, 27(1), 375-382.

Ta N.L, Hoang T.L, Le V.C, Le T.T & Philippe L. (2019) Access to Rural Credit Markets in Developing Countries, the Case of Vietnam: A Literature Review. Sustainability. 88.

Tang, S., Guan, Z.F., & Jin, S.Q., (2010). Formal and informal credit markets and rural credit demand in China. In: *Proceedings of the Agricultural and Applied Economics Association Joint Annual Meeting*, Denver, CO, USA, 25-27 July.

Ukwuaba, I.C., Owutuamor, Z.B., & Ogbu, C.C. (2020). Assessment of agricultural credit sources and accessibility in Nigeria. *Review of Agricultural and Applied Economics Acta Oeconomica,* 21(2), 3-11

Unachukwu, V. C., Tanko, L., Jirgi, A. J. & Yisa, E. S. (2022). Constraints to farmers’ access, utilization and repayment of Bank of Agriculture’s loan in North Central, Nigeria. *Journal of Agripreneurship and Sustainable Development (JASD), 5(*1), 75-81

World Bank (2022). Innovation challenge for agriculture and food security risk financing in southern Africa: https://opportunitydesk.org/ 2020/03/18/world-bank-2020-innovation-challengefor-agriculture-and-food-security-risk-financing-insouthern-africa