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Implementation of Ecosystem-Based Management in the South-South Region of Nigeria: A Coastal Resources and Environment Conservation Approach

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Abstract

The coastal environment within South-South Nigeria (SSN) has suffered significant degradation resulting from the direct and indirect impacts of anthropogenic activities. These include mining, emission of industrial waste, smelting of As-ore, combustion of fossil fuels, notably coal, and disposal of some As-based insecticides, herbicides, and fertilizers into the water bodies. Recently, the conservation of these coastal environments and resources has gained more attention, especially in the face of climate change. Although, various approaches have been established and enforced yet no significant impact. Hence the need for a more efficient and effective approach gave rise to the adoption of ecosystem-based management (EBM) which has aided the effective management of the freshwater resources and environments. This approach acknowledges the complete range of interconnections within an ecological system, involving people, rather than focusing only on particular concerns, species, or ecological services. Implementing EBM has been a challenge due to the diversity of the coastal environment, however, it has been effectively used in the management and conservation of freshwater bodies. This review therefore looks at the possibility of implementing EBM in conserving the coastal environment and its resources. Consequently, a holistic implementation of EBM is however discouraged suggesting an implementation in phases taking into account the unique nature and components of the SSN coastal environment. In addition, the necessary indicators such as organism present, species abundance, thresholds involved, range of threats and disturbances, data evaluation and usage, and monitoring strategies need to be considered.

Keywords: Aquatic pollution; Anthropogenic activities; Climate change; Coastal waters; Resource conservation

INTRODUCTION

The necessity for a suitable management structure that focuses on the conservation of the resources created by this environment is the foundational ground for an economically and socially sustainable coastal environment. Although the meaning of ecosystem-based management (EBM) has no generally acceptable definition, Bentley *et al*. (2021) gave a definition that encapsulates the major tenet of the ecosystem-based management (EBM) approach. From their definition, the EBM is considered a philosophy of environmental management that entails fitting management practices to all types and levels of interaction that occur within and outside the ecosystem. This interaction according to them does not limit itself to fisheries interaction, but also includes the human interaction with the ecosystem (Babatunde, 2020). Thus, the goal of this strategy is to checkmate all types of interaction systematically, with a focus on managing the ecosystem as an integration of multiple subsystems whose actions affect and influence the overall system function. The EBM approach de-emphasizes the management of isolated ecosystem services or parts in favor of seeing the ecosystem as a whole.

From some studies, attention has been drawn to the depletion of the fisheries environment and ocean ecosystem elements which has been attributed to the depredation of the ecosystem (Rice, 2005; Davenport, 2009; Masuga *et al*., 2018). In addition, the poor management strategy was adapted to, either partly or fully managing the ecosystem. Consequently, this gives rise to more research interest by academia and practitioners in fisheries research to study new management approaches that can curtail these depletions of the ecosystem (Browman *et al.*, 2004; Echendu *et* al., 2022; Kleisner *et al.*, 2022). Many benefits have been associated with the practice and use of the EBM approach as a management strategy to manage the aquatic ecosystem. Notably, regional employment generated by fisheries not only contributes to income but also serves as a means of livelihood, while the natural structures within the coastal ecosystem aid in mitigating the impact of extreme weather and safeguarding lives from potential harm (McClanahan *et al.,* 2015). However other authors (including Tallis *et al.*, 2010; Olaoye and Ojebiyi, 2018) have argued against the EBM approach as a management strategy.

Ecosystem-Based Management

In demystifying the concept of the ecosystem-based management approach, the definition ascribed in Bianchi *et al.* (2009) can be regarded as one of the simplified definitions. By their definition, Ecosystem-Based Management is seen as a management system that takes cognizance of the fact that in the ecological environment, plants, animals, and human communities depend on the existence of each other to live and their livelihood depends on their interaction with their physical environment from which an ecological unit (i.e. Ecosystem) is formed. In furtherance of the definition, Samhouri *et al.* (2015) reported that Ecosystem-Based Management is a style of management that is motivated by a clear and concise stated goal that can be implemented by proper policy formation, protocol, and practices, which is based on monitoring and researching further to gain an understanding of the ecological interactions and how this interaction can bring about an ecosystem structure and functioning that is sustainable over time. Thus, EBM seeks to preserve, restore, and/or improve coastal ecosystems and human populations by overcoming the fragmentation of single-sector management techniques and various legislation and governance frameworks, particularly at the land-water interface. It is a framework for managing human-environment interactions, not a single strategy. It differs from other integrated management frameworks in that it focuses on ecosystem-scale management to maintain or restore ecosystem function.

The origination of Ecosystem-Based Management as a management practice stems from the policies used in the Great Lakes ecosystem in North America in the late 1970s (Guthrie, 2017). The essence of the EBM approach has come to stay through a series of tests of common ecosystem management practices. According to Steenberg *et al.,* (2019), before current practices of the EBM approach, a committee set up by the Ecological Society of America (ESA) revealed that there is a need to lay emphasis on the importance of interagency cooperation and improve public awareness which is aimed to challenge the different practices that have been in use for proper park management. This is the underlying foundation for modern ecosystem-based management practices as a management tool.

According to Nnadi *et al.* (2018), the management tenets of the ecological-based management approach are based on accounting for the size and boundary limitation of parks and the re-formation of the park lines. Eckerlin (2010) while studying the relevance of ecological boundary in the framework of EBM, emphasizes that a well-defined ecological boundary is a tenet for a sound EBM strategy. In their study, they came up with the fact that well-state management goals, interagency cooperation, monitoring of management results, and leadership are key to policy formation at the national level.

Implementation of the EBM

Ecosystem-based management requires realizing that the operation of an ecosystem is dependent on complex interactions between various species, habitat types, and human activities (Shabtay *et al*., 2018). While it is neither feasible nor desirable for humans to manage every part of an ecosystem, the crucial work rests in identifying and prioritizing key elements within the context of EBM. The increase in human activity in coastal and marine areas has resulted in severe deterioration in the ecological health of these systems. As a result, the continuous supply of ecosystem services is under imminent threat. Recognizing these concerns, scientists and policymakers generally support using ecosystem-level approaches, such as ecosystem-based management, to address and mitigate them.

According to Long *et al.* (2015), the implementation of the EBM necessitates a broader range of monitoring, including diverse environmental conditions and ecological components in the coastal environment. Traditional monitoring surveys have frequently supplemented existing programs, ensuring temporal consistency. However, this becomes impractical when urgent data demands significant modifications, particularly when distinct ecological components have conflicting requirements (Lee *et al*., 2014). We advocate for a more comprehensive strategy that not only assesses change but also provides evidence for underlying causes of observed changes. We define important features for an integrated monitoring program based on ideas from Barents' Sea observational and modeling studies, as well as larger literature. This approach outperforms a coordinated strategy in terms of operational efficiency.

Integrated monitoring provides advantages over the coordinated approach, which treats ecosystem conditions separately. While integration is necessary to meet current policy requirements, it raises hazards to time-series consistency. Thus, these risks can be mitigated by developing a methodology that permits critical information from less flexible data sources to be incorporated into the assessment.

A systematic discussion on where it has been used.

Ecosystem-Based Management (EBM) has been used in a variety of geographic regions and sectors, demonstrating an increasing acknowledgment of its usefulness in addressing complex ecological concerns (Cucuzza *et al*., 2021). Notably, in the North and Baltic Seas, EBM handles complex relationships between shipping, fisheries, and conversation. Integrated

management plans prioritize diverse ecosystem components to ensure fisheries' sustainability and biodiversity (Rudd *et al*., 2018). Similarly, the Great Barrier Reef Marine Park Authority in Australia uses EBM to manage the unique ecosystem sustainably. The strategy considers water quality, fishing activities, and coral health, all to improve the Great Barrier Reef's overall health and resilience.

To ensure longevity and preservation in the marine and freshwater ecosystem, EBM principles have been incorporated. EBM is used in restoration operations in the Everglades, USA, with a focus on habitat restoration, water flow management, and invasive species control to ensure the health of this unique freshwater ecosystem (Gruss *et al*., 2017). Also, in Europe's Danube River Basin, Ecosystem approaches are used to improve water quality, reduce floods, and conserve biodiversity. Riparian countries' collaborative efforts prioritize integrating water resource management, demonstrating EBM's adaptability in a variety of ecological contexts. Integrated Coastal Management is widely used throughout the East Asian Seas region, including Indonesia and the Philippines (Noor and Abdul Maulud, 2022). In this region, EBM is applied to strike a balance between various economic activities. Furthermore, the use of EBM extends to cross-sectorial activities, as witnessed in the Gulf of Maine, USA. Here, EBM addresses the effect of climate change and ensures a comprehensive approach to its maintenance. Additionally, in the Northeast Atlantic, the Northeast Atlantic Fisheries Organization (NEAFC) utilizes EBM to manage fisheries while taking into account the larger ecological implications. This strategy encourages sustainable fishing techniques and protects vulnerable species, thus demonstrating the efficacy of EBM in solving complex difficulties in marine environments.

The ecosystem approach integrates principles that are essential in both marine and terrestrial ecosystems for long-term conservation and resource management (Galappaththi *et al*., 2023). Yellowstone National Park in the United States exhibits the use of EBM, with efforts focusing on ecological resilience, biodiversity conservation, and maintaining a delicate balance between predator and prey populations. Similarly, the Swiss National Park in Switzerland uses EBM to protect the natural processes and biodiversity of alpine ecosystems, including measures such as wildlife management, habitat protection, and tourist regulations. These applications demonstrate EBM's versatility and effectiveness across a wide range of landscapes and habitats.

Advantages of the Ecosystem-Based Management Approach

Some of the advantages credited to the ecosystem-based management approach are discussed. First, the Ecosystem Management approach is a strategy that is built on suitability and adaptability to the ecosystem environment and it serves as a learning strategy giving room to the reformation and application of the scientific method to management (Woods, 2022). Also, the human environment and the socioeconomic system they exit in are treated by the ecosystem management approach as interdependent factors and as an integral part of the entire ecosystem (Hodbod and Eakin, 2015). Similarly, regarding conflict resolution among and between countries' boundary activities, the ecosystem-based management approach to aids decision-making that facilitates peaceful resolution, and the conservation of the ecosystem is highly stressed (Arbo and Thuy, 2016; Ombara, 2021). Equally, pressure has been continually mounted on managers of both the ecosystem and coastal environment as a result of the need to optimize the value obtained from the ecosystem and the constraining human activity interacting with the system. To reduce this pressure and reconcile the constraining human interaction, Byrnes and Dunn (2020) proposed that the EBM approach will help to increase the value of the ecosystem services and support to the maintenance of the natural environment which will provide the basic needs and wants of

human beings. In the same vein, emphasis is placed more on the level of relatedness and inter-twine between living things in the marine environment and the activities of humans by the ecosystem-based management approach, unlike other approaches that have been in use. Other merits that have arisen from the adoption of the EBM approach have been related to policy formulation, where the EBM approach adopts the scientific procedure which makes it possible for the outcome to be validated and evaluation of effectiveness of the strategy is made possible. Finally as stated by Turner and Schaafsma, (2015), the EBM strategy is built on social value and de-emphasized its foundation on scientific benefits.

Disadvantages of the Ecosystem-Based Management Approach

Though many advantages have been attributed to the use of the EBM strategy, there are some flaws identified by researchers. The ecosystem-based management approach has been flawed on the ground that it lacks a clear and concise definitive element which sometimes limits its scope and application for use as different researchers have had their differences based on their environment and socio-cultural differences. This limits a clear picture of the strategy, which makes its practices to be complex and technical. There is great inadequacy in terms of resources and relevant data that is needed to determine the outcome of the ecological function (i.e. the losses accrued). This hinders the accuracy of evaluating the changes that occur in the ecosystem and habitat characteristics (Regos *et al.,* 2019). Also, the strategy does not provide a framework that accommodates conservation and preservation simultaneously which makes it difficult to engage in both mangrove preservation and shrimp farming (Islam and Shamsuddoha, 2018; Chidi and Bradford, 2020). When the preservation approach of the EBM strategy is used, many investors suffer because their investment potential will be constrained. Certain values have been identified potentials will be constrained. Certain values have been identified to revolve around marine ecosystems and these values are associated with the benefits of using the ecosystem services (i.e. there is an inter-relationship between the benefits of using ecosystem services) which can be in the form of changing physical attributes. By using time series data (which is mostly used in the EBM approach) in predicting the level of association between ecosystem values and services, the outcome usually does not show any form of relatedness, which makes the EBM approach a weak evaluative tool in determining the values of the ecosystem and services (Leslie *et al.,* 2015; Heymans *et al.,* 2016; Olsen *et al.,* 2016). For the EBM approach to be effective and yield the expected outcome, the size of the ecosystem that it is adapted to needs to be large enough (i.e. in terms of the marine environment, the coastal environment, and the human environment and its activities). This makes it not to be universally adaptable since smaller ecosystems cannot use this strategy (Levin and Mollmann, 2015). Also, the EBM strategy lacks jurisdiction definition and boundary limit making conflict inevitable (Macpherson *et al.,* 2023). For a more pragmatic result to be obtained from the use of the approach, the practice at all levels of governance is expected to be the same, but due to political jurisdictional differences that exist in the different layers of governance, many variances tend to occur.

Suitability of the Ecosystem-Based Management Approach

The ecosystem-based management approach has come to be seen as a widely acceptable strategy as the economic valuation of the aquatic products is made possible and a better understanding of the changes that occur in the ecosystem services as a result of habitat conversion is gained (Olusanya and Ajagbe, 2022).

The EBM strategy according to Reach *et al.* (2022), has a major focus in its revolution races which are, first, how the environment affects and impacts the natural resources (which includes the Aquarian resources) that are subject to

exploitation, secondly how the resources exploited affect and influence the behavioral response of the environment (i.e. determining the potential contribution of the environment). According to the report of Ahakwa *et al.* (2023), they emphasized that this two-way interaction between the exploited natural resources and the environment has the potential to affect other resources which will affect the level of output of the exploited resources due to their connection to their surrounding ecosystem.

Buhl-Mortensen *et al.* (2017) also emphasized the suitability of the strategy by stating that its application encompasses different facets of the marine environment all of which lead to the sustenance of the ecosystem. According to them, the strategy can apply to oceanic management, fisheries production and management, marine pollution control, establishment and management of tourism, and Aquarian management. Also, Alexander and Haward (2019) stated that the use of the EBM strategy made it possible for the degradation of marine ecosystems and the factors leading to the degradation, which can also extend to studying the causes of pollution in the ecosystem, destruction to physical habitat and possible disease spread which all may affect the climatic changes thereby affecting the introduction of new species to the marine system.

With the EBM approach, instead of individual sectorial agencies managing their activities everywhere independently, responsible sectorial authorities can work in synergy to manage all human activities and their interaction with the ecosystem (Cormier *et al.*, 2019). The Aquarian environment requires that proper knowledge be developed to support and guide the management of the system. By applying EBM as a management tool, the necessary understanding relating to procedures involved in ecological processes that affect the marine and coastal ecosystem can be gained. With the EBM approach also, the regulatory system framework in terms of legislation and political influence affecting the Aquarian environment can be provided. Also, the EBM approach can be a tool for integrating a strategic plan that aids the management and control of human activities affecting the coastal environment. One of the focal points calling for attention and requisition of a management tool for coastal management is the depletion of marine fish and other product populations. Levin and Mollmann (2015) stated that with the EBM approach, the depleted marine resources can be rebuilt and regained in as much as the strategy is effectively implemented. Andrade (2018) has recognized the importance of place in addressing the interaction of humans and the marine environment since the activities of humans cannot be separated from the activities that go on in the marine environment.

Challenges Faced in the Implementation of the EBM Strategy

In the quest to implement the ecosystem-based Management approach and make it functional, a lot of challenges have been identified. One major challenge facing the implementation of the EBM strategy is the lack of a well-defined management unit. As stated by Ansong *et al.* (2017), bioregion can be an effective management unit that can facilitate proper implementation of the EBM strategy. He also states that a functional unit should be established for managers to compare against which is seen as a big challenge.

Creativity is a basic necessity and requirement needed for the implementation of the EBM strategy and this is a major challenge as management and governing bodies are always constrained with the ability to form a creative administrative body structure. Limited knowledge of the ecosystem component, function, and time has also been attributed to constraining the successful implementation of the EBM strategy and making it a short-term focus (Brooker *et al.*, 2018; Delacámara *et al.*, 2020).

There is a lack of knowledge about how effective and efficient the ecosystem can be, and also there are limited available resources to support its

functional activities and implementation. Another challenge facing the implementation of the strategy is that its formation has been based on the foundation of analogy and comparison which might have resulted from duplicating other approaches. Rudd *et al.* (2018) identify the financial and technical abilities of countries as part of the constraints that limit the successful implementation of the strategy.

Coastal resources (water bodies) of the South-South Region of Nigeria

Coastal areas in the South-South region of Nigeria are dynamic habitats that combine terrestrial, marine, and freshwater systems. These areas are already home to about 25 million people, or 40% of the population (Ehirim *et al.*, 2018; Ayyam *et al.*, 2019). Also, nearly everyone depends on coastal resources for essential services such as food, employment, recreation, energy, and other critical needs. Coastal areas are becoming more desirable for development and tourism. Coastal ecosystems in these zones are sensitive to anthropogenic influences such as excess nutrients, invasive species, sea level rise, harsh weather, and oil spills. Coastal ecosystems include beaches, estuaries, coastlines, wetlands, salt marshes, mangroves, coral reefs, seagrasses, and other vital habitats for marine wildlife (Ayyam *et al*., 2019; Cooley *et al.*, 2022). However, extreme occurrences characterized by extraordinarily high temperatures, highly acidic conditions, or extremely low oxygen levels pose significant threats to marine ecosystems and the coastal communities that rely on them. According to the projections of Shiru *et al.* (2020), the frequency and intensity of these rare events will rise, exposing vulnerabilities that necessitate change and management. This includes promoting technical breakthroughs for detecting, forecasting, and reducing adverse conditions.

Coastal zones are currently experiencing significant and prolonged environmental stresses from a range of driving forces. Responsible agencies around the world are diligently exploring strategies to more effectively manage both the root causes and repercussions of environmental changes in the coastal areas (Talbot *et al*., 2018). Amid the relentless and cumulative global environmental change spurred by factors such as urbanization, trade, population growth, industrial development, liberalization of transnational corporation activities, and capital flows, the world's coastal zones are under increasing pressure. These zones harbor a diversified range of assets, including human populations as well as physical and ecological resources. When properly managed sustainably, these regions have the potential to provide considerable prospects for wealth development as well as the maintenance and enhancement of general quality of life. The loss of biodiversity can have a negative influence on the functioning and adaptation of ecological systems, reducing the availability of important products and services.

Obstacles to sustainable coastal resource development results from a lack of political momentum to invest in the governance structures required to resolve complex connections in coastal zones. Existing institutions stifle adaptive responses to ecosystem changes, resulting in congestion and misunderstanding in environment management vested interests and an inability to demonstrate the net social advantages of an integrated strategy contribute to the slow development in integration initiatives. The lack of scientific understanding of coastal dynamics adds to the challenge. To demonstrate the benefits of integrated management, compare strategies with and without integration. The integrated assessment framework incorporates coupled models and is a participative approach that brings together knowledge from several scientific areas. Taking a historical perspective on socioeconomic-natural system interaction is critical for enhancing coastal management research. Due to permanent consequences, unexpected outcomes, and unforeseen changes in coastal zones, policy responses must be flexible, as conditioned by the precautionary principle and

safe minimum requirements (Williams *et al*., 2018). Future consultation processes should take a more active and conciliatory approach with stakeholders, emphasizing the social, political, and economic reasons for expanding participatory roles. The sustainable use of coastal resources is inextricably tied to the economic, political, and legal frameworks.

Recommendation

Based on the challenges and disadvantages attributed to the use of the EBM approach, there is a need for more research work to be conducted to ascertain more about its effectiveness as a management tool. Also, all facets of governance and implementing bodies need to be effectively monitored to curtail the disparities that exist among the implement bodies. This institutional body should be equipped with all the managerial capacities for conflict resolution should conflict arise as a result of the different approaches and strategies that may be adopted. Also, managers and all concerned persons who work in the marine and coastal environment are expected to have the needed skills and build their knowledge horizon.

The proper use of the EBM strategy is founded on the grounds of a sound, strong, and reliable structure that will accommodate the different sectorial bodies that have a role in the implementation of the strategy. A management system that can sustain the true nature of our biological environment, with consistencies in the productivity of the marine and coastal ecosystem is highly recommended.

Policymakers and managers need to move from the era of sectorial activities management oriented to an ecosystem-based activities management, where policy and decision are taken based on the ecosystem and not just a particular sector base.

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SPATIO-TEMPORAL EFFECTS OF LAND USE AND LAND COVER CHANGE ON CLIMATE VARIABLES IN NIGER DELTA REGION, NIGERIA

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ABSTRACT

The natural land cover of the oil-producing Niger Delta Region of Nigeria is being altered at an alarming rate despite the strong nexus between land use and land cover change (LU/LCC) and the global climate change. Hence, this study investigated the trend of LU/LCC in the Region and its relationship with climate variables (CVs). Landsat 5, 7, and 8 images of 1986, 2004, and 2022, respectively, were utilized. Thermal bands of the landsats were used for land surface temperature (LST) determination. CVs were acquired from NASA Earth Observatory and WorldClim databases. Supervised Maximum Likelihood was used to classify the landsat dataset into 5 LU/LC types (Dense vegetation (DV), water, wetland, farmland/sparse vegetation (FV), and built-up). Mono-window algorithm and correlation were used to estimate LST, and the relationship between LU/LC and CVs. DV, wetland, and water body lost 1,937.59km^2, 464.1km^2, and 164.2km^2, respectively, while built-up and FV gained 1,423.70 km^2 and 1,142.15 km^2, respectively. LSTs were moderately low and exhibited increasing trend within the study period. High LSTs were observed in built-up areas, while moderate to low LSTs were observed in other LU/LC types. The mean rainfall, wind speed, and relative humidity were notably high and exhibited an irregular pattern. Areas closest to the seacoast consistently showed higher rainfall. DV (-1.00), water body (-0.71), and wetland (-0.95) had negative relationship with built-up; FV had negative correlation with DV (-1.00), wetland (-0.96), and water body (-0.68), and a positive relationship with built-up (1.00). Built-up had a direct relationship with LST. Evidently, CVs change with the change in LU/LC types.

Keywords: Climate change, Climate variables, Land surface temperature, NDR, Remote sensing.

INTRODUCTION

Land use and land cover (LU/LC) refer to the utilization and physical attributes of land. All human activities on the land, such as farming, urbanization, and the maintenance of habitats for wildlife and flora are regarded as land use (Kanianska, 2016). To meet human needs, land is used in a variety of ways (for forest, agriculture, bare-land, industrialization, water body, urbanization/built-up, mining, among others). The extent to which an area or region is covered by impermeable surfaces, wetlands, forests, agriculture, and other land and water types is revealed by land cover information (Chowdhury *et al.,* 2020). Whether for mixed-use, development, or conservation, land use reveals how people use the environment. Thus, (LU/LCC) is the term used to describe the changes in land cover brought about by human modification of land uses. When LU/LC are treated jointly, both represent the physical cover and human imprints on the land (Abbas, 2013).

The process of LULC is complex, influenced by both natural and human factors (Wessels *et al.*, 2004). Many

researchers have linked changes in LULC in different areas (such as delta regions) to broader global change phenomena (Dale 1997; Turner *et al.,* 2007; and Alexander *et al.,* 2018). In recent times, the Niger Delta Region (NDR) has witnessed increasing LU/LC changes, resulting in widespread environmental challenges that require careful mapping (Abbas 2013; Emenyonu *et al.,* 2015). The growing demand for urbanization, industrialization, and agricultural land globally highlights the scarcity of land resources and underscores the need for informed decision-making regarding their optimal utilization in the NDR of Nigeria (Emenyonu *et al.,* 2015).

The Delta regions are recognized as economic and environmental hotspots, covering only 1% of the Earth's surface but accommodating over 7% of the global population (Ericson *et al*., 2006). Tropical delta areas, such as the Niger Delta, face several pressures, including rise in sea-level, salinity intrusion, erosion, and floods, exacerbated by the climate crisis (Szabo *et al.,* 2016; Nababa *et al.,* 2020). The Niger Delta River (NDR) stands as Africa's largest river delta, witnessing a rapid increase in human population (Nababa *et al*., 2020). It hosts the continent's largest mangrove forest, crucial for local communities' livelihoods, fisheries, flood protection, and cultural practices (Zabbey *et al.,* 2010; Numbere, 2014; Okonkwo *et al.,* 2015). However, this valuable ecosystem faces threats from oil and gas exploration, mangrove overexploitation, urbanization, and invasive species like the Nipa palm (*Nympa fruticans*), water hyacinth (*Eichhornia crassipes*) (Balogun *et al.,* 2015; Duke, 2016; Nwobi *et al.,* 2020; Onyena *et al.,* 2020).

Despite its significance, reliable and up-to-date information on land cover dynamics, especially regarding mangrove forests, remains scarce in the Niger Delta (Nababa *et al*., 2020). Few studies have mapped land cover changes in the region concerning climatic variables. Given the significant changes in LU/LC over the years due to human activities, concerns have emerged regarding their impacts on climatic variables in the Niger Delta (Emenyonu *et al*., 2015). Understanding the interactions between LU/LCC and climatic variables is crucial for crafting sustainable development strategies and climate resilience planning in the region. Thus, this study evaluated the spatio-temporal effects of LU/LC change on climatic variables in the NDR of Nigeria over 30-year time series.

MATERIALS AND METHODS

The Study Area

The study was conducted in the NDR, which is in southern Nigeria and borders the Gulf of Guinea to the south. The Niger River splits into multiple tributaries, which eventually end at the Atlantic Ocean's coast. It lies between latitudes 4° 20' and 6° 05' N and longitudes 5° 20' and 8° 45' E. The area spans across several states (Delta, Rivers, Bayelsa, Akwa Ibom, Abia, and Cross River) (Hogan, 2013; Umoh *et al.,* 2022). However, the area coverage of this study cut across Rivers, Akwa Ibom and Abia states (Figure 1). The region is one of the most significant wetland areas in the world, characterized by a network of creeks, rivers, swamps, and rich biodiversity (Abbas, 2013; Okonkwo *et al.,* 2015). It is also a petroleum-rich region and has extensive pollution challenges (Chidumeje *et al.,* 2021; Ukhurebor *et al.,* 2021). Oil and mineral exploration, subsistence farming and fishing are the dominant occupation in the region (Fasona, 2003). The temperature ranges between 24°C to 32°C, while the rainfall ranges between 3000- 4500mm (Nwilo and Badejo, 2006).

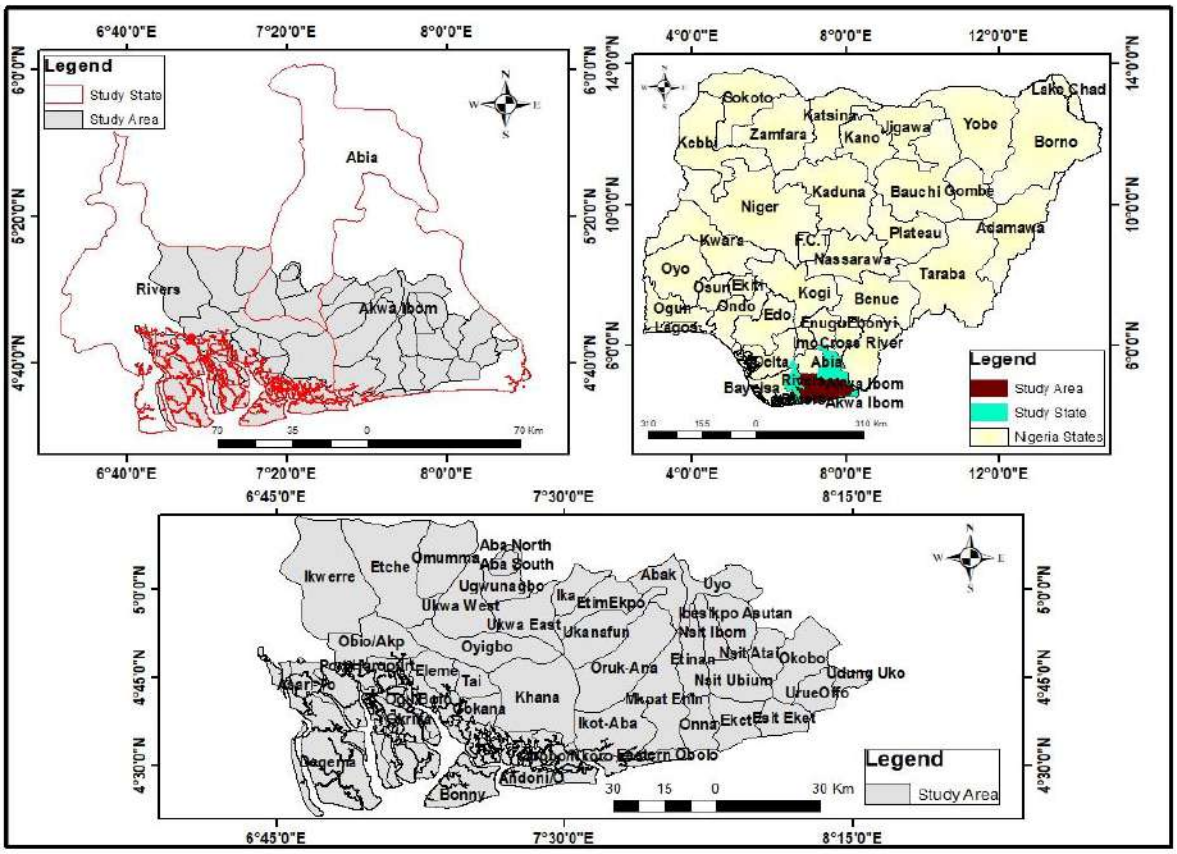

Figure 1: Map of the Study Area

Data Acquisition

Landsat 5, 7 and 8 of same season (path 188 / row 057) in time sequence of 1986, 2004 and 2022 were obtained from United States Geological Survey (USGS). The climatic variables of the study years were acquired from NASA Earth Observatory and WorldClim databases. Ground truth points were randomly collected from different LULC types with the aid of Garmin Geographic Positioning System (GPS). The attributes of the Landsat imageries used are presented in Table 1.

TABLE 1: FEATURES OF LANDSAT IMAGERIES

Landsat Features	1986	2004	2022
Scene ID	"LT518805719863 53XXX10"	"LE71880572004365AS N00"	LC81880572022036LG N00
Path/row	188/057	188/057	188/057
SpaceCraft ID	Landsat 5	Landsat 7	Landsat 8
Sensor ID	TM	L7_ETM	OLI-TIRS
Spatial Resolution	30m	30m	30m
Acquisition Date	19/12/1986	31-12-2004	12/02/2022
Datum/UTM	WGS84/32	WGS84/32	WGS84/32
Grid cell size	30	30	30
K1	607.76	666.09	774.8853
K2	1260.56	1282.71	1321.079

Data Processing and LU/LC Classification

Landsat imageries were processed, enhanced, and geometrically corrected to the World Geodetic System (WGS) 1984 using Ground Control Points (GCP), and projected to Universal Transverse Mercator (UTM) zone 32N coordinate system in

ARCGIS 10.8. The spatial extent of the study area was extracted from the administrative shapefile of Nigeria using "Extract by Mask" function in ARCGIS. Following the field reconnaissance survey and the ground control points on the various LU/LC types, supervised maximum likelihood was adopted to categorize the study area into various LU/LC types in IDRISI and ARCGIS software.

Table 2 shows the various LU/LC types identified and classified. Kappa coefficient was employed to determine the accuracy of the classification using the ground control points obtained during field ground truth exercise, and the historical map of the study area. Area coverage of each LU/LC types was determined using Raster calculator in Arc toolbox. The changes in each LU/LC category were calculated between two time periods (initial time and subsequent time), Ubaekwe *et al.* (2022), Kindu *et al*. (2013), and Demissie *et al*. (2017), as expressed below.

$OC(Km2) = X_2 - X_1$ equation [1]

$RA\left(\frac{Km2}{yr}\right) = \left(\frac{X_2 - X_1}{t}\right)$ equation [2]

Where: OC = Observed change; X_1 = Area coverage of LU/LC type at the initial year.

X_2 = Area coverage of LU/LC type at the subsequent year; RA = Rate of change per annum; t = time interval between initial and subsequent years.

Table2: LULC Types and Description

S/No	LU/LC Types	Description
1	Water body	Areas including river, ocean, sea, stream.
2	Wetland	Ecosystem characterised mainly by swamps, marshes, bogs.
3	Dense vegetation	Areas of thick vegetation types
4	Farmland/sparse Vegetation	Agricultural land, and scattered vegetations
5	Built-up	Areas of physical structures, including settlements, roads, plain surfaces

Land Surface Temperature Retrieval

The LST of the research area within the study periods were retrieved using the thermal bands of 1986, 2004 and 2022. Among other methods of LST estimation, the mono-window algorithm was used based on its precision and wide applications, as used by Liu and Zhang (2011) and Sobrino *et al*. (2004). The described steps below according to Qin *et al*. (2001) were employed:

A: Transformation of Digital Number (DN) to Spectral Radiance

$\text{Radiance} = \left(\frac{(L_{MAX} - L_{MIN})}{Q_{CALMAX} - Q_{CALMIN}}\right) X (Q_{CAL} - Q_{CALMIN})$ equation [3]

Where: Radiance = (Watts/m^2.ster.μm), Q CALMIN= 1, L_{MIN} = minimum spectral radiance at Q CAL= Digital Number, Q_{CAL}, L_{MAX}= maximum spectral radiance at Q_{CAL}, Q_{CALMAX}= 255

B: Conversion from Radiance to Brightness Temperature (in degree Celsius)

$T = \frac{K_2}{\ln\left(\frac{K_1}{L\tau} + 1\right)} - 273.15$ equation [4]

Where T = At-Satellite Brightness Temperature, K_1 = Calibration constant 1 ($Wm^{-2}sr^{-1}\mu m^{-1}$) , Lλ = Top of Atmosphere

(TOA) spectral radiance, K_2 = Calibration constant 2 (Kel) ,

C: Estimation of Land Surface Emissivity (LSE)

LSE = $0.004Fv + 0.986$

$$FV = \left(\frac{NDVI - NDVI_{Min}}{NDVI_{Max} - NDVI_{Min}}\right)^2 \quad \text{equation [5]}$$

$$\text{NDVI} = \frac{\text{NIR} - \text{RED}}{\text{NIR} + \text{RED}} \quad \text{equation [6]}$$

Where: Fv = Fraction of vegetation, NDVI = Normalized Difference Vegetation Index

D: Estimation of LST

$$\text{LST} = \frac{BT}{1+w} X \frac{BT}{P} X \ln(e) \quad \text{equation [7]}$$

$$\text{P} = hX\frac{C}{S}(1.438\text{x}10^2\text{mK}) \quad \text{equation [8]}$$

Where: BT = At-sensor brightness temperature, h = Plank's constant, s = Boltzmann constant, c = velocity of light, w = wavelength of emitted radiance, e = LSE

Estimation of Rainfall, Relative Humidity, and Wind Speed

Phan and Nguyen (2023) and Wango *et al*. (2018) compared the average climatic data from NASA Earth Observatory and WorldClim databases with the climatic data from ground weather stations and recorded non-significant difference. Thus, the **a**nnual rainfall, relative humidity, and wind speed of 1986, 2004 and 2022 of the study area were obtained from the databases as previously done by other researchers (Akinbobola *et al*., 2023; and Wang *et al*., 2021).

Using daily data, the monthly mean and total yearly relative humidity and mean wind speed values were calculated for the research periods using the equation [8] for each location. Based on proximity, some local governments have same climatic features; hence, thirty-five-point locations from 35 local governments were purposely selected from the 42 local governments under study, as the representative sample. The annual relative humidity and mean wind speed were computed for each location using equations [9] and [10], respectively.

$$\text{RH} = \sum_{i=1}^{12} \text{RH i} \quad \text{equation [9]}$$

$$\text{Ws} = \sum_{i=1}^{12} \text{Wsi} \quad \text{equation [10]}$$

The high spatial resolution at 30s, 2.5 min, 5 min, and 10 min of WorldClim v2.1 in GEOTIFF format was used to map out the spatial distribution pattern, maximum and minimum rainfall for the years 1986, 2004 and 2022 of the study area in ARCGIS environment (Akinbobola *et al*., 2023). Each grid cell in the raster denotes a distinct geographic area and carries a value that reflects the total amount of rainfall in that location. The minimum and maximum rainfall for each year was used to compute the mean annual rainfall.

Relationship between LU/LC Types and Climate Variables

Pearson correlation matrix was used to ascertain the relationship between LU/LC types (water, wetland, farmland/sparse vegetation, dense vegetation, built up) and climate variables (relative humidity, wind speed, rainfall, LST) in the study area. A perfect negative association is represented by a correlation coefficient of -1, no association is represented by a correlation coefficient of 0, and a perfect positive association is represented by a correlation coefficient of 1. Overlay analysis and spatial autocorrelation were further carried out between LST map and LU/LC map of same year to evaluate their spatial relationship.

RESULTS

Spatio-Temporal Distribution and Area Coverage of LU/LC of the NDR, Nigeria

The LU/LC map of the research area for the years: 1986, 2004 and 2022 are revealed in Figures 2, 3, and 4, respectively. Five (5)

LULC types were identified and categorized as built-up, water body, wetland, farmland/sparse vegetation, and dense vegetation. Dense vegetation dominated the area throughout the study periods in decreasing trend of 6196.69km^2 (63.23%) in 1986, 5412.00km^2 (55.23%) in 2004, and 4259.11km^2 (43.46%) in 2022 (Table 3 and Figure 5) respectively. Similar trend was observed in wetland ecosystem, the spatial extent decreased from 1326.01km^2 (13.53%) in 1986, to 1029.86km^2 (10.51%) in 2004, and 861.92km^2 (8.80%) in 2022. Spatial extent of built-up and farmland/sparse vegetation exhibited an upward trend within the study periods. Built-up increased from 834.28km^2 (8.51%) in 1986 to 1349.29km^2 (13.77%) in 2004, and extremely increased to 2258.03km^2 (23.04%) in 2022. Farmland/Sparse vegetation increased from 546.25km^2 (5.57%) in 1986, to 999.84km^2 (10.20%) in 2004, and 1688.45km^2 (17.23%) in 2022. Water body exhibited an irregular pattern of spatial extent. It increased from 896.25km^2 (9.15%) in 1986 to 1008.47km^2 (10.29%) in 2004 and reduced to 731.95km^2 (7.47%) in 2022.

These finding reveal the gains, losses, and the rate of changes in LU/LC of the study area (Table 4). Loss was recorded at varying rates under wetland (296.15km^2) and dense vegetations (167.94km^2).Wetland lost 296.15km^2 and 167.94km^2, at the varying rates of 16.45km^2/yr and 9.33km^2/yr between 1986 – 2004, and 2004 – 2022, respectively. Dense vegetation had a lostof784.69km^2 and 1152.89km^{2}at the rates of 43.59km^2/yr and 64.05km^2/yr between 1986 – 2004 and 2004 – 2022, respectively. In contrast, built-up gained 515.01km^2 and 908.74km^{2}at the rates of 28.62km^2/yr and 50.49km^2/yr; farmland/sparse vegetation also gained 453.59km^2 and 688.61km^{2}at the rates of 25.20km^2/yr and 38.26km^2/yr between 1986 – 2004 and 2004 – 2022, respectively. Water body gained 112.23km^2, at the rate of 6.23km^2/yr between 1986 – 2004, lost 276.52km^2 at the rate of 15.36km^2/yr between 2004 – 2022.

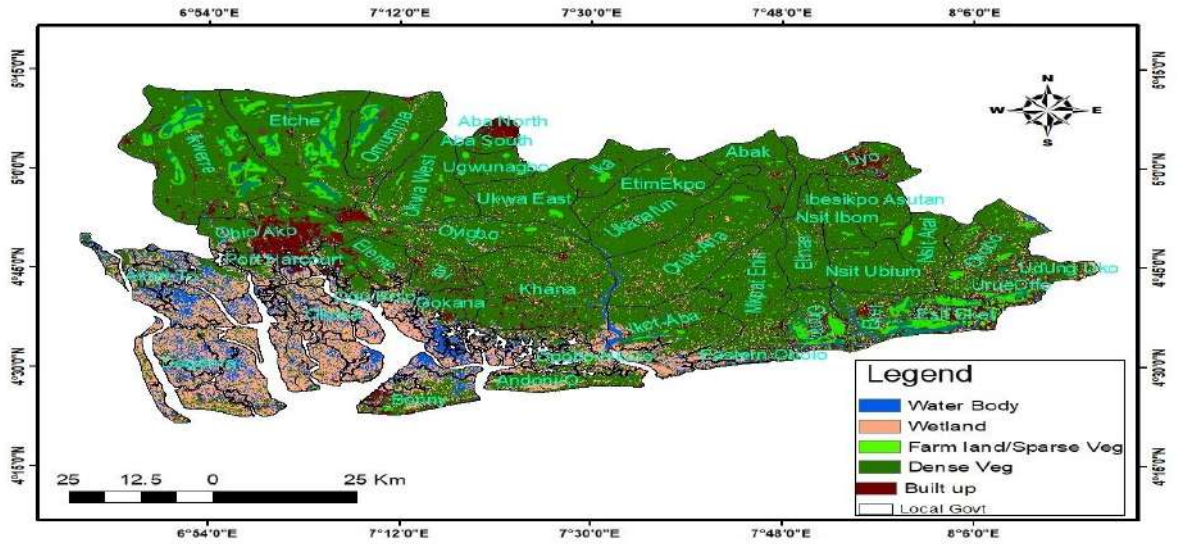

Figure 2: 1986 Land Use Land Cover (LU/LC) of Niger Delta Region, Nigeria

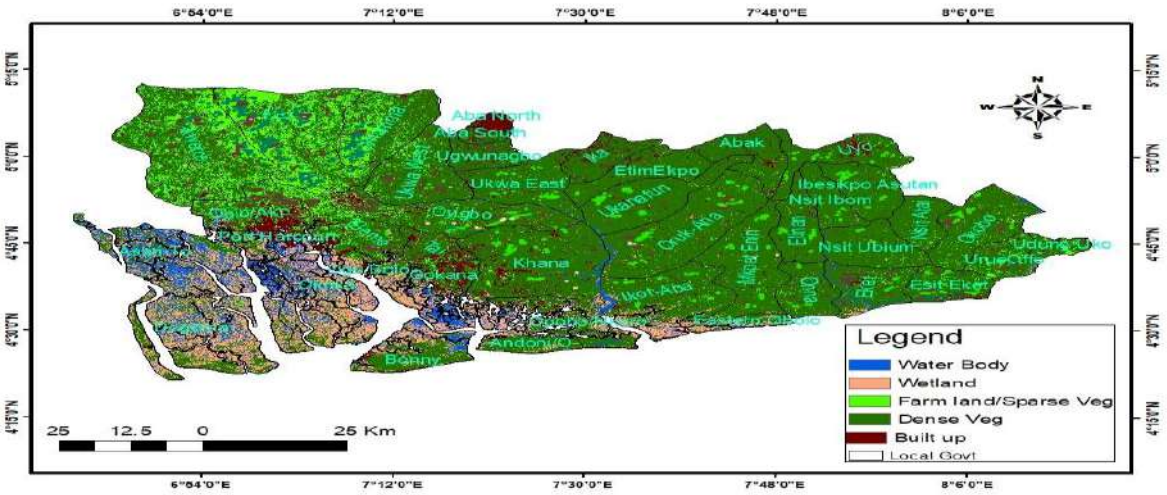

Figure 3: 2004 Land Use Land Cover (LU/LC) of Niger Delta Region, Nigeria

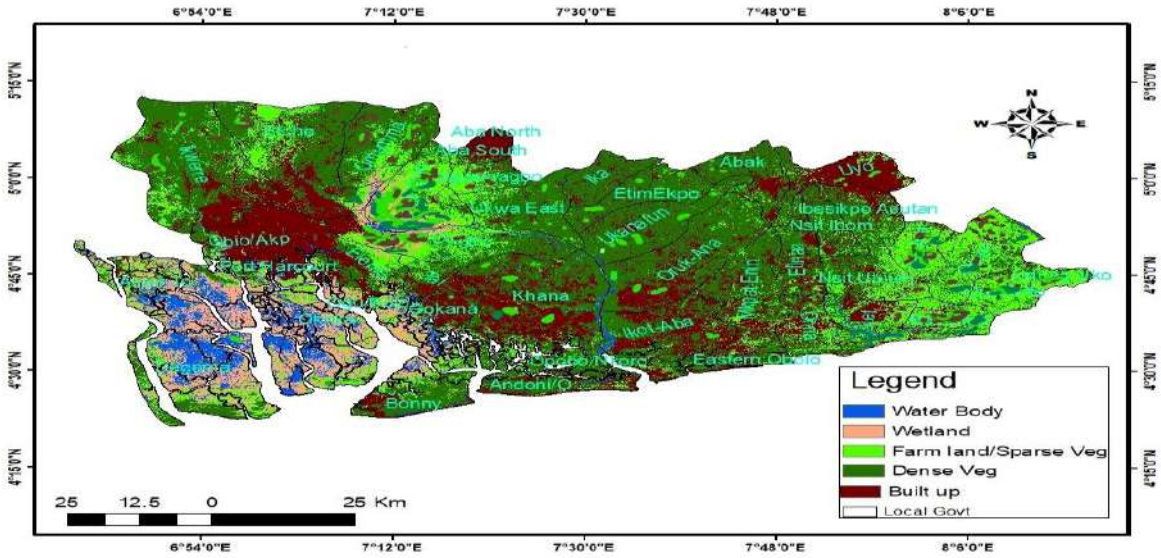

Figure 4: 2022 Land Use Land Cover (LU/LC) of Niger Delta Region, Nigeria

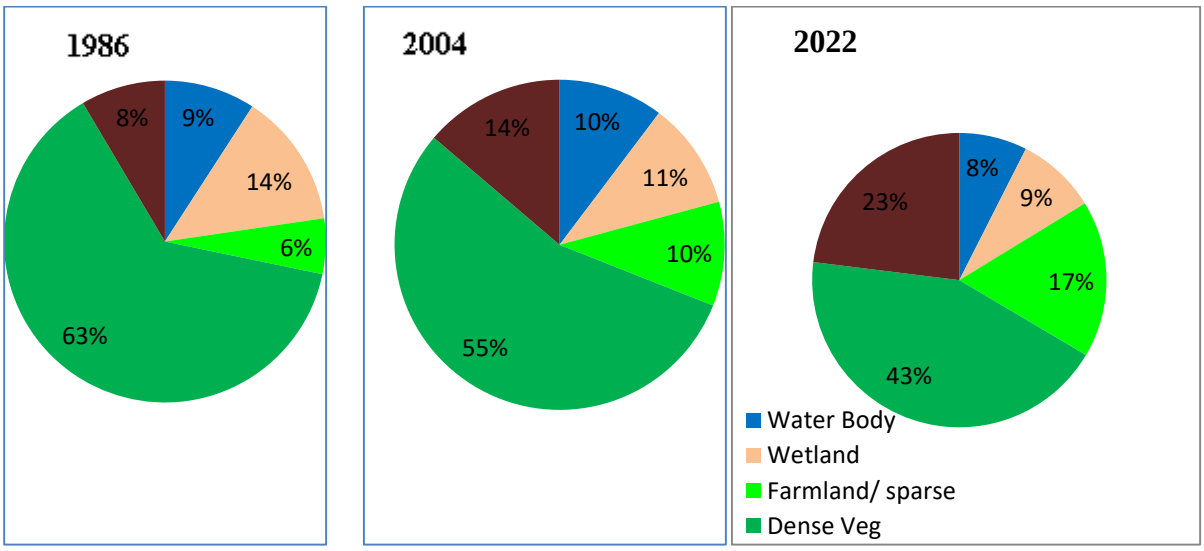

Figure 5: Percentage Fraction of Each Land Use Land Cover (LU/LC) Types in Niger Delta Region, Nigeria

Table 3: Variation in Land Use Land Cover (LU/LC) Types

Time series (year)	Water	Wetland	Farmland/sparse Vegetation	Dense Vegetation	Built up
1986	896.2±2.0^{b}	1326.0±10.0^{a}	546.3±10.0^{d}	6196.7±4.4^{a}	834.3±4.0^{d}
2004	1008.5±5.0^{a}	1029.9±9.0^{b}	999.84±4.0^{c}	5410.7±0.6^{b}	1349.3±7.8^{c}
2022	732.0±1.7^{d}	861.9±10.0^{c}	1688.45±9.2^{b}	4259.11±13.8^{c}	2258.0±2.0^{b}
***p*-value**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**

Mean with dissimilar superscript on same column are statistically different at 0.05 levels.

Table 4: Observed Changes and Rate of Change of Land Use Land Cover (LU/LC) Types from 1986 – 2040

LULC	Observed Change (Km^2) 1986 - 2004	Change Rate (km^2/Yr)	Observed Change (Km^2) 2004 - 2022	ChangeRatekm^2/Yr)
Water body	112.23	6.23	-276.52	-15.36
Wetland	-296.15	-16.45	-167.94	-9.33
Farmland /Sparse	453.59	25.20	688.61	38.26
Dense Veg	-784.69	-43.59	-1152.89	-64.05
Built up	515.01	28.61	908.74	50.49

Spatio-Temporal Distribution of LST and Rainfall

The results on spatial distribution of LST (Figures 6 to 8) revealed areas of high, moderate to high values of LST. The maximum and minimum LST exhibited a growing trend through the study years. In 1986, maximum and minimum LST was 27.25^{o}C and 18.38^{o}C, respectively. It increased to 30.28^{o}C maximum and 19.12^{o}C minimum in 2004; and increased to 34.61^{o}Cmaximum and 21.68^{o}C minimum in 2022. The spatial rainfall distribution also showed areas of high, moderate to low rainfall in 1986, 2004 and 2022. The rainfall pattern (Figure 10) exhibited an irregular trend. The maximum and minimum annual rainfall in 1986 was 3073.12mm and 2158.25mm, respectively. The year 2004 experienced a moderate increase of maximum (3166.49mm) and minimum 2276.97mm, while a sharp decrease of maximum (2518.30mm) and minimum (1872.61mm) was recorded in 2022.

Temporal trend of mean LST across LU/LC types within the study periods (Figure 9) followed a regular trend throughout the study periods. Water body had the least mean LST, followed by wetland, farmland/sparse vegetation, dense vegetation. However, built-up had the highest mean LST.

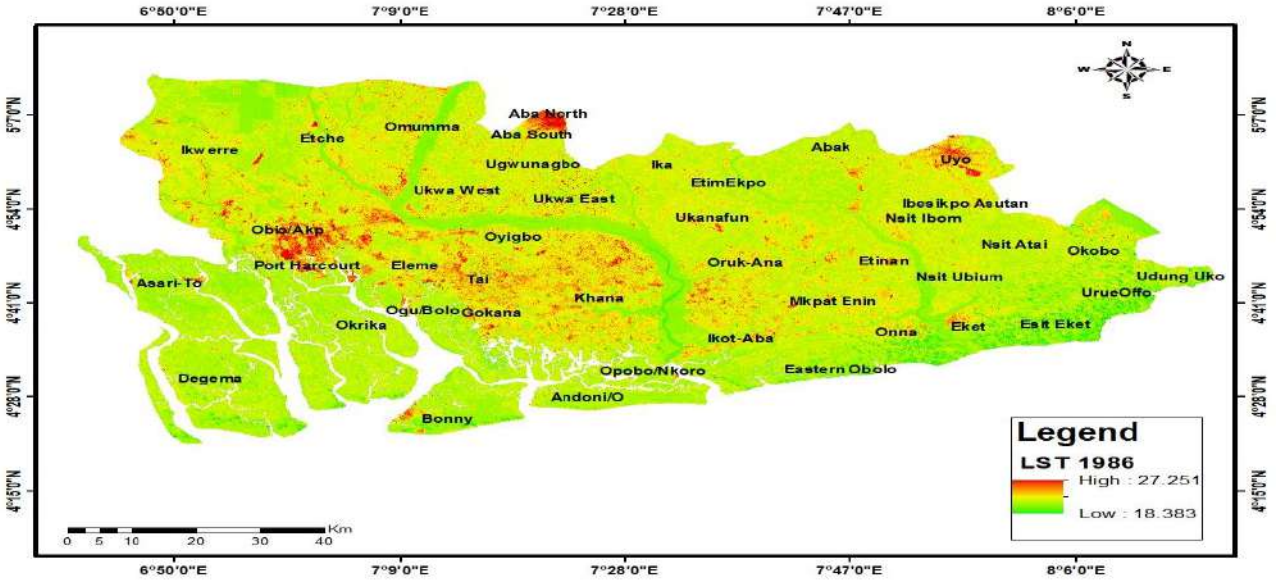

Figure 6: Spatio-Temporal Distribution of LST of Niger Delta Region in 1986

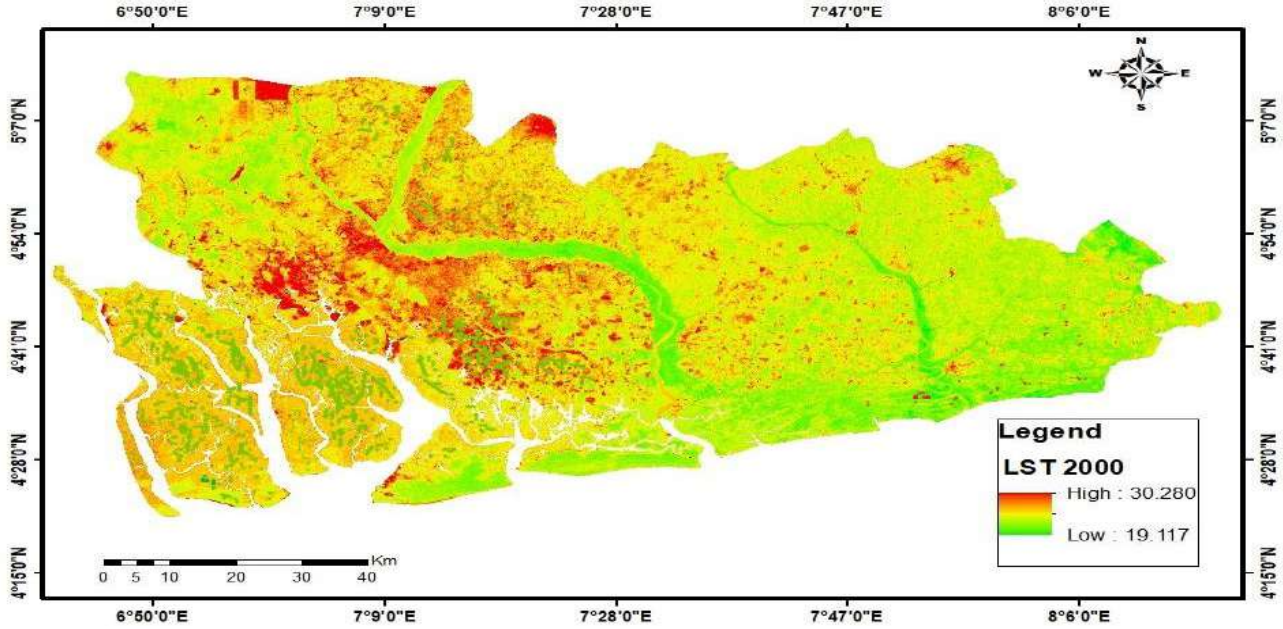

Figure 7: Spatio-Temporal Distribution of LST of Niger Delta Region in 2004

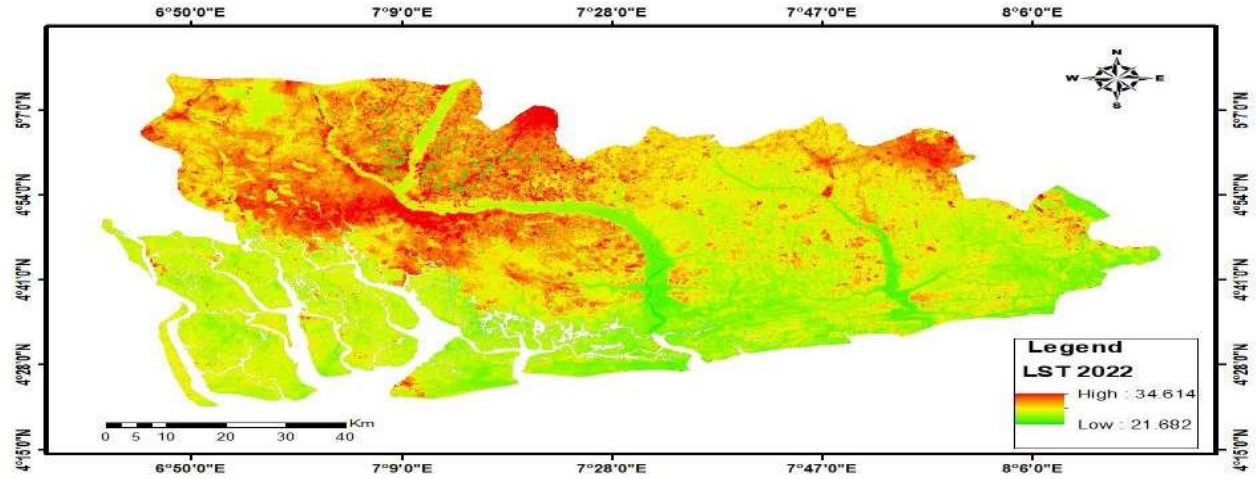

Figure 8: Spatio-Temporal Distribution of LST of Niger Delta Region in 2022

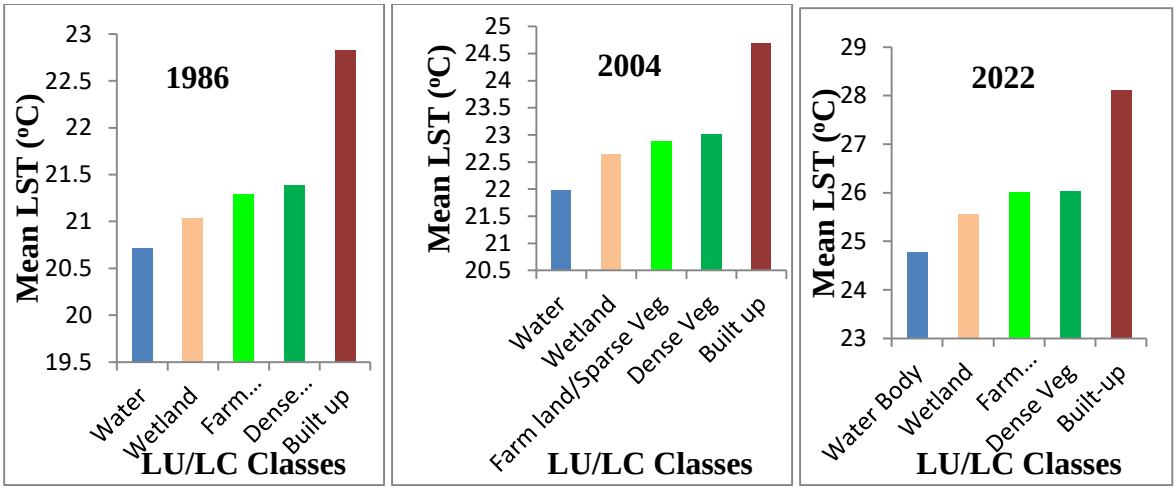

Fig. 9: Temporal Trends of Mean LST across LU/LU Types in 1986, 2004 and 2022

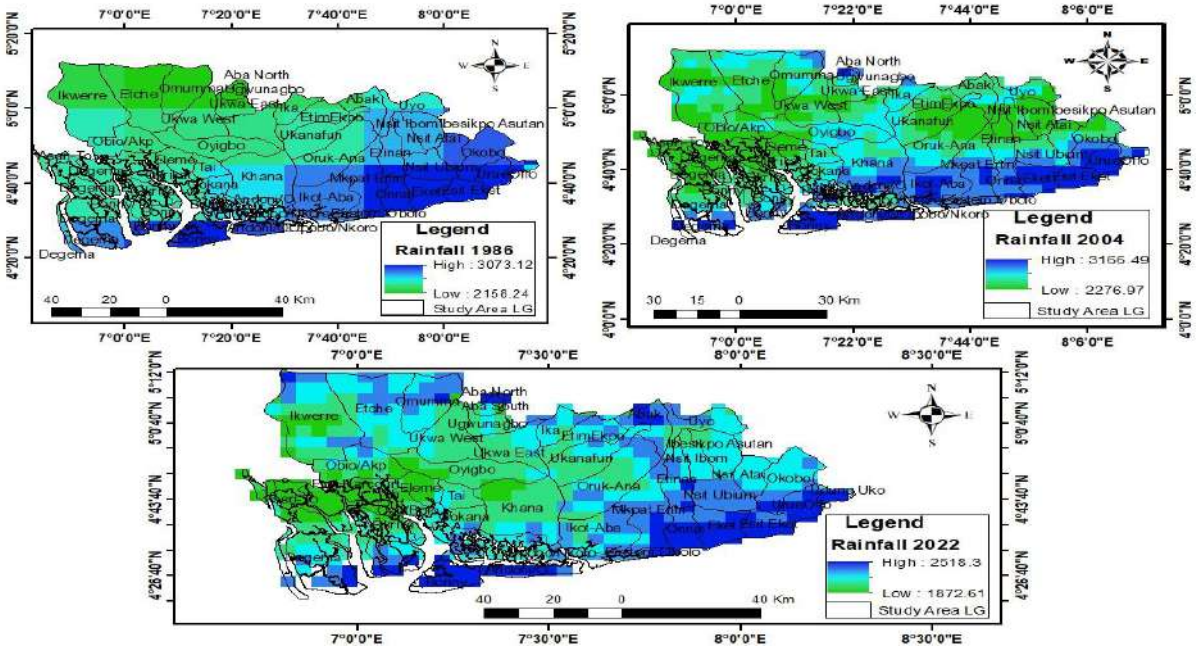

Figure 10: Spatio-Temporal Distribution of Rainfall of Niger Delta Region within the Study Periods

Changes in Climatic Variables of the Study Area within the Study Periods

There are notable changes in the climatic variables within the study periods. Mean relative humidity remained relatively stable; with slight fluctuations from 86.43±8.3% in 1986 to 87.67±1.5% in 2004 and 86.07±9.5% in 2022(Table 8).Mean wind speed was 2.45±1.0m/s, 2.49±1.0m/s and 2.29±1.0m/s in 1986, 2004 and 2022, respectively. There was variability on mean rainfall across the (Table 5).Maximum mean rainfall was recorded in 2004 (2721.7±10.0mm), followed by 1986 (2615.7±15.0mm) and least in 2022. Mean LST experienced a consistent increase over the years, from 22.8±1.7^{o}C in 1986, to 24.7±1.9^{o}C in 2004 and 28.2±11.1^{o}C in 2022. The results indicated changing climatic/environmental conditions in the study area. Average relative humidity and average wind speed exhibited significant differences ($p > 0.05$) while mean rainfall and mean LST showed significant difference over time ($p = 0.000, 0.519$)

Table 5: Variation in the Climatic Variables of Niger Delta Region (NDR) within the Study Periods

Time series (year)	Mean Relative Humidity (%)	Mean Wind speed (m/s)	Mean Rainfall (mm)	Mean LST (°C)
1986	86.43±8.3^{a}	2.45±1.0^{a}	2615.7±15.0^{a}	22.8±1.7^{a}
2004	87.67±1.5^{a}	2.49±1.0^{a}	2721.7±10.0^{a}	24.7±1.9^{a}
2022	86.07±9.5^{a}	2.29±1.0^{a}	2195.5±5.0^{b}	28.2±11.1^{b}
***p*-value**	**0.413**	**0.968**	**0.000**	**0.519**

Mean with dissimilar superscript (alphabet) on same column are statistically different at 0.05 levels.

Relationships between LU/LC Types and Climatic Variables

Pearson correlation matrix (Table 6) revealed the relationship between LU/LC types and climatic variables in the study area. Water body had a strong positive correlation with rainfall (0.98), wind speed (0.97), relative humidity (0.91). There was a strong negative correlation between water body and LST (-0.72) and built-up (-0.71). Also, there was moderate positive and negative correlation between water body and dense vegetation (0.68) and farmland/sparse vegetation (-0.68). Wetland had strong positive association with dense vegetation (0.96), average positive relationship with wind speed (0.64), rainfall (0.64) and strong negative association with LST (-0.95), built-up (-0.95) and farmland/sparse vegetation (-0.96).

Farmland/sparse vegetation had a perfect negative and positive correlation with dense vegetation (-1.00), built-up (1.00) and LST (1.00), and strong negative correlation with rainfall (-0.83) and wind speed (-0.83). Dense vegetation had a perfect negative correlation with built-up (-1.00) and LST (-1.00), and strong positive correlation with wind speed (0.82) and rainfall (0.82). Built-up, had a strong negative correlation with wind speed (-0.85) and rainfall (-0.85), and a perfect positive correlation with LST (1.00). Relative humidity had strong positive correlation with wind speed (0.80) and rainfall (0.80), and weak negative correlation with LST (-0.37). Wind speed had a perfect positive relationship with rainfall (1.00) and strong negative association with LST (-0.86), while rainfall had a strong negative association with LST (-0.85).

Table 6: Pearson Correlation Matrix on Land Use and Climatic Variables of the Study Area

	Water	Wetland	Farmland/ Sparse	Dense Veg	Built-up	Rel. Humidity	Wind speed	Rainfall	LST
Water	1.00	-	-	-	-	-	-	-	-
Wetland	0.46	1.00	-	-	-	-	-	-	-
Farmland/ Sparse Veg	-0.68	-0.96	1.00	-	-	-	-	-	-
Dense Veg	0.68	0.96	-1.00	1.00	-	-	-	-	-
Built up	-0.71	-0.95	1.00	-1.00	1.00	-	-	-	-
Rel. Humidity (%)	0.91	0.06	-0.33	0.32	-0.37	1.00	-	-	-
Wind speed (m/s)	0.97	0.64	-0.83	0.82	-0.85	0.80	1.00	-	-
Rainfall (mm)	0.98	0.64	-0.83	0.82	-0.85	0.80	1.00	1.00	-
LST (°C)	-0.72	-0.95	1.00	-1.00	1.00	-0.37	-0.86	-0.85	1.00

DISCUSSION

Spatio-Temporal Distribution and Area Coverage of LU/LC of the Region

The LU/LC of the research area were basically dense vegetation, water body, wetland, built-up and farmland/sparse vegetation. This result is similar with the report of Elekwachi *et al*. (2021) who worked on LU/LC types in the NDR of Nigeria. Generally, the entire study area is predominantly dense vegetation throughout the study periods. However, areas like Degema, Bonny, Ogu-Bola, Opobo/Nkoro and Asari-Toru were consistently dominated by wetland and water body; while Obio/Akpo, Port Harcourt, Aba North and Uyo were consistently dominated by built-up. Each of these LU/LC type has experienced changes, losses, and gains at varying rates due to many factors.

The decreasing trend in dense vegetation, wetland, and the increasing trend in built-up and farmland/sparse vegetation area were similar to the trend of LU/LCC reported by Elekwachi *et al* (2021) in NDR, Wizor *et al*. (2020) in Obio/Akpo Local Government, Ubaekwe *et al*. (2022) in Finima Nature Park, Bonny Local Government Area. Elekwachi *et al*. (2021) attributed the decreasing trend of dense vegetation and wetland to human population increase and the associated demand for more agricultural land, settlement, and commercial activities. These invariably elevated the areas of built-up as well as the areas of farmland/sparse vegetation. Elekwachi*et al.* 2018 also reported a decrease in wetland area of Port Harcourt Local Government Area because of extreme urban slump and rapid conversion of wetland to housing development.

Tariku *et al*. (2020) recorded decrease in areas of Abaya-Chamo wetland because of swift population growth, farm extension, overgrazing, and the damage of natural vegetation closest to the wetland. They also reported that the high rate of Abayo-Chamo wetland degradation was triggered by absence of strong regulations and legal actions on the exploitation, and poor protection of wetland resources. Obiefuna *et al*. (2013) also recorded rapid decline in Lagos wetland ecosystem and linked the loss to urban development. The inconsistent trend in the area coverage of water body was also observed by Elekwachi *et al.*(2018). Additionally, Collins and Elekwachi (2020) recorded a significant decline in area coverage of water body in Obio/Akpo Local Government Area within the study period of 2000 to 2018. Both studies linked the decline in water body to urban development and human population growth.

Spatio-Temporal Distribution of LST and Rainfall

LST is an important parameter that determines the energy exchange and surface radiation controlling the heat distribution between the surface and atmosphere; it changes as a result of many factors. In this study, the minimum and maximum LST were moderately low in 1986 and increased with the years within the study periods. Similar trend was recorded by Koko *et al*. (2021) in Abuja metropolis; and Eyoh and Okwuashi (2017) across the NDR. The latter recorded minimum and maximum LST of 19.40ºC and 29.89ºC in 1986; 19.8ºC and 30.9 ºC in 2002 and 19.9ºC and 31.1ºC in 2016.

The values were almost same with the values recorded in this study; however, the very slight differences could be attributed to the larger coverage of areas in NDR in their study. The former recorded minimum and maximum LST of 20.30ºC and 37.11ºC in 1990, and 20.58ºC and 40.13ºC in 2019. The mean LST in Abuja Metropolis were significantly higher when compared with the mean LST in the NDR. The minimum and maximum LST recorded in the study area were also low when compared with minimum (23.86^0C) and maximum (34.39^0C) LST recorded by Traore, et *al*. (2021) in 1986; and compared favourably with the minimum (19.85°C) and maximum (29.22°C) LST in 1999; minimum (21.35°C) and maximum (35.23°C) LST in 2021 in the city of Bangui southern part of Central African Republic and in northern Oubangui river bank. The variations in the minimum and maximum LST over the years indicated traces of climate change in the region.

Different LU/LC types exhibited varying range of mean temperature in the study. Spatially, areas of water body exhibited the minimum mean LST, followed by wetland; farmland/sparse vegetation, dense vegetation, while built-up exhibited the highest mean LST. In other words, changes in any LU/LC types will directly and indirectly affects the mean LST. Eyoh and Okeke (2017) reported similar trend in a study on the relationship between LU/LC change and LST across the NDR of Nigeria. Their findings showed that water body, mangrove, forest, low density built-up and high density built-up had increasing mean LST of 21.59°C, 22.73°C, 22.94°C, 24.75°C, and 27.96°C respectively.

Bharath *et al*. (2013) and Traore *et al*. (2021) also reported elevated values of LST in plain regions and cities when compared with low LST recorded in dense vegetation. The authors concluded that the presence of impermeable objects, asphalt, low albedo materials have high capacity to absorb solar energy and convert into thermal energy thereby increasing the surface temperature; whereas dense vegetation, wetland, farmland, and water body have higher albedo, thus reflecting more sunlight and reducing the amount of solar radiation being absorbed. Liu

et al. (2015) and Qijiao and Zhixiang, (2015) added that high rate of evapotranspiration in dense vegetation has a cooling effect on the land surface which lowers the mean LST compared to built-up areas with little or no vegetation. These explain the spatial variations in LST distribution across different local governments in the study areas. The temperature in Aba North, Obior/Akpo, Uyo and Port Harcourt Local Government Areas were significantly higher than the LST in Ukwa East, Ukanafun, Degema, Andoni, etc.because of different surface materials and anthropogenic activities in the locations.

The range of annual rainfall recorded in the study area is extremely high when compared with the annual mean rainfall of 1033.95mm, 1098.85mm, 1079.61mm and 660.01mm in the years 1987, 1997, 2007 and 2017 respectively according to Mngube *et al.* (2020) in the Mara River Basin, Kenya; the mean annual rainfall of 2400mm, 1400mm and 2050mm reported by Wang *et al*. (2021) in the years 2001, 2011 and 2019 respectively in Guangdong–Hong Kong–Macao; and the mean annual range of 2,208mm and 1,662mm recorded by Akintuyi *et al*. (2021) in the derived savannah region of Nigeria between the years 1941 - 2019. However, the mean rainfall in the study area compared favourably with the report of Akinbobola *et al*. (2023). They recorded mean rainfall of 2350mm between the year 2000 – 2004; 2300mm between the years 2004 – 2009; 2250mm between the years 2009 – 2014; and 2550mm between the years 2015 – 2020 in the NDR. The high rainfall confirmed in the NDR could be traceable to the Atlantic Ocean situated within the region. Spatially, areas closest to the coast received consistent high rainfall throughout the study periods, while areas away from the ocean depicted an irregular pattern.

Akinbobola *et al*. (2023) reported that Atlantic Ocean offers maritime humid trade winds which bring forth moisture to the land; and that the region is characterised by highlands which enhances orographic processes that result to rain. Rosenfeld *et al*. (2019) in agreement added that areas closest to the Atlantic Ocean experience more and frequent rainfall due to the combine effects of maritime, sea breezes, convergence zones and topographic effects. There were variations in the mean relative humidity and mean wind speed across the study years; however, the variations were not significantly difference. The variability both in spatial distribution and amount of rainfall and LST recorded in this study is an evidence of climate change. This assertion was supported by Akinbobola *et al*. (2023), Mngube *et al* (2020) and Wang *et al*. (2019), they added that the climate change was exacerbated by rapid LU/LC changes.

Relationships between Land Use and Climatic Variables of the Research Area

Correlation matrix shows the relationship existing between land use/land cover types and the climatic variables. Among the LU/LC types, built-up area is the major factor of decrease in dense vegetation, wetland and water body, and had caused increase in farmland/sparse vegetation. This supports the assertion by Ubaekwe *et al*. (2023), Elekwachi *et al* (2021), Ubaekwe *et al*. (2022), Wizor *et al*. (2020), Tariku *et al*. (2020) that human population growth, urbanization, industrialization and poor policy implementation are the major factors of forest loss, water and wetland encroachment. Farmland/sparse vegetation had perfect negative correlation with dense vegetation, and strong negative correlation with wetland and water body. However, increase in spatial extent of farmland/sparse vegetation decreases to a greater extent the area coverage of dense vegetation, wetland, and moderately water body. The observed strong positive correlation between dense vegetation and wetland in this study supported the studies by Smith *et al*. (2018) and Jones and Brown, (2015). This linear

relationship highlights the intricate and mutually beneficial ecological interplay between the two natural landscapes. According to Smith *et al*. (2018), Jones and Brown (2015), the wetland features such as water availability, rich soil nutrient, water flow control and high nutrient cycling processes provide favourable conditions for vigorous and rapid vegetation growth; while dense vegetation provides habitat and cover to wetland ecosystem, thus contributes to its resilience and stability against human disturbances and ecological pressures.

Changes in dense vegetation can lead to changes in the wetland ecosystem, and conversely, changes in the wetland can affect the dense vegetation. In addition, the observed moderate relationship among water body, dense vegetation and wetland also confirm the interdependency of the components. The strong positive correlation between water body, rainfall, wind speed and relative humidity reveals that increase in rainfall will directly increase the relative humidity, water body and wind speed. This explains why areas closest to the seacoast had highest amount of rainfall. Smith and Johnson (2015) supported the assertion and added that rainfall is one of the major factors that affect water body formation, water levels and sustainability. More so, high relative humidity enhances cloud formation, which can result to rainfall; while strong winds cause waves and currents in water bodies, which help in water movement (Johnson, 2019).

Considering the five-land use/land cover types and other climatic variables, increase in dense vegetation, water body, wetland, wind speeds and rainfall decreased LST, while increase in built-up increased LST and decreased wind speed and rainfall. This relationship is similar to the report of Eyoh and Okeke (2017), Koko *et al*. (2021). This explains why areas with high built-up densities such as Aba North, Obior/Akpo, Port Harcourt, and Uyo exhibited high temperature when compared with the areas of high vegetation densities like Ukwa west, Ukanafun, Etche, a phenomenon often referred to as urban heat island. Ashwini and Sil (2022), explained that elevated wind speeds and rainfall cause decline in LST since heat from the surface which causes high temperature are being dissipated by wind, while rainfall through direct cooling effects of evaporation and increased moisture content in the air moderates land surface temperature.

CONCLUSSION

This study revealed the major LU/LC patterns in the study area, and the changes occurring over time and their relationships with climate variables. Dense vegetation emerged as the dominant land cover type, while water bodies exhibited the least area coverage. However, each land use/land cover category experienced significant changes in spatial extent, with gains observed in built-up and farmland/sparse vegetation, and losses in dense vegetation, wetlands, and water bodies.

The analysis of land surface temperature (LST) revealed a moderate to low range, with an increasing trend observed from 1986 to 2022. Built-up areas consistently exhibited higher LST values compared to other land cover types. Additionally, the study observed high rainfall levels, particularly in areas close to the seacoast. Wind speed and relative humidity displayed similar spatial patterns with rainfall across the study periods.

Significant relationships were identified between land use/land cover types, climate variables, and their interactions. Negative correlations were observed between dense vegetation, water bodies, wetlands, and built-up areas, while farmland/sparse vegetation showed positive associations with built-up areas. Furthermore, inverse relationships

were observed between dense vegetation, water bodies, wetlands, wind speeds, rainfall, and LST. Water bodies exhibited direct relationships with relative humidity, rainfall, and wind speed.

The study has revealed the impact of changes in LU/LC on climate variables, indicating the importance of proper land management practices. To address environmental challenges, aggressive protection measures for wetland ecosystems, forest vegetation, and water bodies are recommended. Additionally, promoting urban greenery and implementing sustainable urbanization strategies, such as green roofs and permeable pavements, can mitigate adverse effects on the environment. Ultimately, effective land use and cover management are essential for mitigating climate change and preserving ecological balance in the NDR.

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ASSESSMENT OF LAND MANAGEMENT PRACTICE AND SOIL CONSERVATION AMONG MAIZE-BASED FOOD CROP FARMERS IN SOUTHWEST, NIGERIA

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ABSTRACT

The study examined the determinants of various land management practices and conservation methods on maize farmers' output in Southwest, Nigeria. Multistage sampling technique was used to select 480 maize farmers in the study area. Interview schedule was used to elicit needed information such as age, land conservative/management practice and production characteristics of maize farmer in the study area. Data were analyzed using descriptive statistic and stochastic production function (SPF). The result revealed that 70.8%, 70.5% and 89.2% were male, married and literate respectively with mean household size estimated at 4 persons. The result showed that 33.0%, 9.2% and 1.0% adopted planting cover crop, mulching and fertilizer application as means of land management practices respectively; while 28.3% and 48.3% of the farmers adopted crop rotation and mixed cropping as land conservation practices. SPF showed that farm size ($p<0.01$), labour ($p<0.01$), land management practice ($p<0.01$) and land conservation practice ($p<0.01$) have a significant influence on maize production in the study area. Land management and land conservation practices were determinant factors in maize production. The study recommended that government should encourage farmer-specific research to create on how to improve quality of farm management practices.

keywords: Land Management, Crop rotation; Mulching; Stochastic Production Function, Cover crops,

INTRODUCTION

Land is the major resource for the livelihood of the poor. In Nigeria, a typical villager recognizes land in its entirety. Oluwatayo *et al.* (2008) reported that land to the farmer is like home and work place and shares it with the entire biotic complex. As important as land is to farmers' livelihood, Arimi (2014) observed that subsistence farmers are with a lot integrating constraints on land management practices. These constraints are classified into three: economics obstacles such as capital need and financial incentives; social conditions which include land tenure, availability of infrastructures and educational level of farmers; and ecological consideration such as limited knowledge of inputs and sustainability of some systems. Land use, in many African nations, has been characterized by a significant amount of land degradation. Moreover, these two processes are clearly related. Many poor African pastoralists and farming households respond to declining land productivity by abandoning existing degraded pasture and cropland, and moving to new land for grazing and crop cultivation. Appropriate management practices have to be adopted because the pattern of land use will often result into depletion of soil nutrients. Oluwatayo *et al*. (2008) noted the need for appropriate soil management in tropical soil to sustain increased crop yields as cultivation continues on an annual basis. This was traced to the fact that clay in most tropical soil, referred to as low activity clay

(LAC) does not expand and contract readily with moisture changes and the soil becomes susceptible to soil compaction. Also, LAC soils have a low cation exchange capacity, which means that nutrients are not held by the soil, but quickly leached below the crop roots. This is due to high temperature; which makes organic matters in tropical soil to be susceptible to rapid mineralization (Omotoso et al., 2023).

Furthermore, in an imperfect market setting, the nature of poverty is also important in determining its impact on natural resources management and degradation. Households that are not poor by welfare criteria such as minimum levels consumption may still face "investment poverty" that prevents them from making profitable investments in resource conservation and improvement.

The study was informed by the declining food crop production in Nigeria. Food crop production in Nigeria no longer keeps with population growth. Thus, creating a wide gap between the demand and supply of food (Abdulrahman, 2013). This is evidence in the observed food crop deficit and the upward trend in the price of foodstuff in the market over the years (Food and Agriculture Organisation, 2006). The growth of Nigeria economy with reference to agriculture has been import driven rather than production driven (Omotoso and Omotayo, 2024). Consequently, there is a growing advocacy for improving Nigeria agricultural production so as to achieve sustainable food security. According to Abdulrahman (2013), a lot of effort has been directed at finding appropriate institutions for organizing millions of small-scale farmers towards achieving food security (through increased food crops production) and agricultural productivity. Food production could be affected by the farmer's age, access to credit, gender, farm size, educational level and farming experience. It is on record that 50% of world's population is dependent on subsistence agriculture. The effect of this is high, underfeeding and malnutrition throughout the nation. Nigeria as a nation mainly depends on rural inhabitants who constitute over 15% of the total population for the production of foods (FAO, 2006). These farmers are poor subsistence farmers who spend little on food production, which lead to low productivity.

Moreover, Nigeria is witnessing an upward trend in price of foodstuff, which should not be attributed to inflationary tendencies alone (FAO, 2006). The price increase is mainly due to decrease in production coupled with rise in demand as a result of increase in population and purchasing power (Omotayo et al., 2022). For example, cassava products were reported to be declining by less than 10% for reasons connected with losses from livestock and declining soil fertility which is a result of the effect of land productivity (Amaza and Olayemi, 2000). Hence, there is every need to increase food crop production due to increase in human population so as not to cause hunger and starvation among the teeming population (Omotoso et al., 2022).

This study was therefore conceived to determine the technical efficiency of maize production in Ogun State, Nigeria. Hence, the specific objectives are to describe the socioeconomic characteristic of maize farmers, examine the type of land management and conservation practices adopted by maize farmers and determine the effect of land management practices on Maize production in the study area.

MATERIALS AND METHODS

Study area

The study was carried out in Ogun State, South Western Nigeria. The State lies between longitudes $2^{0}2^{1}$ and $3^{0}55^{1}$ and latitudes $7^{0}01^{1}$ and $7^{0}18^{1}$. It has a tropical climate with rainforest vegetation on its southern part and a derived savannah on its

northern end. It has an estimated land area of 16,409.26 square kilometers and it is characterized commercially by a dual economic focus, the bourgeoning industrial sector and a dominant agricultural sector. The vegetation is largely rainforest and savannah and this makes it possible to cultivate many crops ranging from tree crops to arable crops and food crops. The farmers in the State cultivate crops, such as, maize, cowpea, cassava, melons, cashew, cocoa, oil palm, and vegetables.

Sampling procedure and Data collection

The study populations were mainly rural farming households who engaged in maize crop production in the study area. Multistage sampling method was used to select 240 farming households from 20 communities in two Agricultural Development Programme (ADP) zones of Ogun State. First stage involved the selection of two Zones which are Abeokuta and Ilaro randomly. Second stage involved simple random selection of three (3) blocks from Abeokuta Zone and two (2) blocks from Ilaro ADP zone. Stage three involved random selection of four (4) cells from each of the 5 blocks making 20 cells. While the last stage involved random selection of twelve (12) farming households from each of the 20 cells making 240 farming households. Primary data were collected using structured interview guide. Data were analyzed using frequency count, percentage, mean and Stochastic Production Function

RESULTS AND DISCUSSION

Socioeconomic characteristics of respondents

The socioeconomic distributions of the respondents were presented in Table 1. Distribution of age of the food crop farmers in the study area as shown in Table 1 reveals that majority (94.17 percent) of food crop farmers were aged below 61 years with the mean age of 43 years. The result was in conformity with Adebayo (2014) who pointed out that individuals were more active under the age of 50 years. This implies that most of the respondents are in their economically active age and are expected to be energetic and productive. Also, many (72.5 percent) of the food crop farmers were married with mean household size of 4 persons. Also, based on religion distribution of the respondents, majority (60.0 percent) were Christians. Distribution of food crop farmers by educational status revealed that many (50.8 percent) had secondary school education as against 10.8 percent without formal education. The mean farming experience and farm size were estimated at 9.6 years and 4.2 hectares respectively. This is contrary to Dipeolu *et al.* (2009) where majority of food crop farmers had no formal education while Arimi (2014) reported that majority of Nigeria's farmers are still subsistence in nature. Also, majority (72.5 percent) of food crop farmers had contact with extension agents once a year. This finding aligned with Fabusoro *et al.* (2008) that shortage of extension personnel hindered the delivery of good agricultural extension services.

Table 1: Distribution of the respondents according to the socioeconomic characteristics in Ogun State

Socioeconomics characteristics	Frequency	Percentage	Mean
Sex			
Male	170	70.83	
Female	70	29.17	
Age			
Less than 30	52	21.67	
31-40	48	20.00	
41-50	88	36.67	43
51-60	38	15.83	
61 and above	14	5.83	
Marital status			
Married	174	72.50	
Single	52	21.67	
Divorced	10	4.17	
Widowed/widow	2	0.83	
Separated	2	0.83	
Religion			
Christianity	144	60.00	
Islam	88	36.67	
Traditional	8	3.33	
Level of education			
Non-formal	26	10.83	
Primary	40	16.67	
Secondary	122	50.83	
Tertiary	52	21.67	
Household size			
1-2	68	28.33	
3-6	142	9.17	4
7-10	28	11.67	
10 and above	2	0.83	
Farm size			
1-5 hectares	180	75.00	4.19
6-10 hectares	16	6.67	
11-15 hectares	26	10.83	
16 and above	18	7.50	
Farming experience			
1-5 years	66	27.50	
6-10 years	94	39.17	9.6
11years and above	80	33.33	
Contact with extension agent			
None	4	1.67	
Once	174	72.50	
More than once	62	25.3	
Total	**240**	**100**	

Distribution of the respondents based on the various land management practice adopted in Ogun State

Table 2 revealed the various land management practices adopted by maize farmers in the study area. It was revealed that 2.50% of the respondents did not engage in any form of land management practices, 3.34% of the respondents engaged in Terracing, 1.67% of the respondents engaged in contour bonds, 1.67% of the respondents engaged in Ridge across slope, 5.83% of the respondents engaged in Crop rotation, 35.0% of the respondents engaged in Multiple cropping, 32.5% of the respondents engaged in Cover Cropping, 9.17% engaged in Mulching, none of the respondents was engaged in Agro-forestry, 2.50% of the respondents engaged in bush fallowing, 5.0% of the respondents engaged in compost, while 0.82% of the respondents engaged in Fertilizer Application. This implies that Majority of the respondents are engaged in various land management practices.

Table 2: Distribution of the respondents based on the various land management practice adopted in Ogun state

Land Management Practice	Frequency	Percentage
None	6	2.50
Terracing	8	3.34
Contour Bonds	4	1.67
Ridge Across Slope	4	1.67
Crop Rotation	14	5.83
Multiple Cropping	84	35.00
Cover Cropping	78	32.50
Mulching	22	9.17
Agro-Forestry	0	0.00
Bush Fallowing	6	2.50
Compost	12	5.00
Fertilizer Application	2	0.82
Total	**240**	**100**

Land conversation practices adopted by the respondents

Land conservation practice adopted by maize farmers in the study area was revealed in Table 3 that 28.33% of the respondents engaged in crop rotation, 13.33% of the respondents engaged in Bush fallowing, 48.33% of the respondents engaged in Mixed cropping, 8.33% of the respondents engaged in Planting cover crop while 1.67% of the respondents engaged in Mulching. This implies that majority of the respondents were engaged in diverse land conservation practices in the study area.

Table 3: Distribution of respondents according to land conversation practices adopted in Ogun state

Land conservation methods	Frequency	Percentage
Crop Rotation	68	28.33
Bush Fallowing	32	13.33
Mixed Cropping	116	48.34
Planting Cover Crop	20	8.33
Mulching	4	1.67
Total	**240**	**100**

Maximum Likelihood Estimates of the Stochastic Production Function of Maize farmers

Table 4 presents the maximum likelihood estimates (MLE) of the production function of maize farmers in Ogun State. The variance parameter for sigma-square for maize farmers was estimated at 0.741. The sigma-square attests to the goodness of fit and correctness of the distributional form of the model while the gamma value (0.641) which was significant at 5% revealed the systematic influences that were unexplained by the production function and the dominant sources of random error. This implies that about 64.1% of the variance in output of maize farmers in Ogun State is due to the differences in their technical inefficiencies or technical efficiencies.

The result showed that hired labour and farm size in hectares had positive significant influence on maize production at 1 percent. Furthermore, the finding showed that other variables such as fertilizer, agrochemical and cost of planting materials/input didn't exert any significant influence on maize production in the study area.

The contribution of farmers' personal characteristics such as Age, Years of education, farming experience, household size and sex, land management practice, land conservative practice to farm inefficiency were also examined. However, all the variables examined in the inefficiency model are not significant except land management practices and land conservative practice that had negative influence on farmers' inefficiency model. This implies that land management practices and conservations practices by farmers in are predominant factors in maize production in the study area.

Table 4: Stochastic Frontier Production Function Model result of Maize farmers' production in Ogun state

Variables	Coefficient	Standard error	t-value
Constant	0.6231***	0.2115	2.9460
Farm size	0.4510***	0.1521	2.96515
Labour (Man days)	0.7211***	0.2007	3.5929
Fertilizer (Kg)	0.2981	0.3092	0.9641
Agrochemicals (Kg)	1.0134	0.7022	1.4431
Planting material/input (₦)	0.0207	0.0332	0.6234
Inefficiency Model			
Constant	2.1311**	1.0763	1.9800
Sex	0.5671	0.5231	1.0841
Age	0.0033	0.1128	0.0292
Education	-0.2091	0.3121	-0.6699
Farm Experience	-0.7711	0.9899	-0.7789
Household size	-0.2219	0.3441	-0.6448
Land Management Practice	-0.1952***	0.0522	-3.7394
Land Conservative Practice	-0.6493***	0.2316	-2.8035
Diagnostic Statistics			
Stigma-square (δ^2)	0.741	1.586	0.467
Gamma (γ)	0.641**	0.311	2.061
Log Likelihood	-116.21		
Chi Square	32.21***		

CONCLUSION

The study concluded that majority of the respondents were still in their economic stage, married and expected to be productive. The result of SPF revealed that hired labour and farm size in hectares exert a positive influence on maize production in the study area.

The study recommends that researchers should be result oriented, specified their researches on specific food commodity and create awareness on how to improve the quality of farm management practices currently in practice. There is need for the government to add to the present subsidy style (credit facilities support) through subsidized planting materials, inorganic fertilizers and agro-chemicals as well as provision of soft loan to farmers who were unable to benefit directly from the credit subsidies to remain in agriculture

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ASSESSMENT OF CLIMATE CHANGE IMPACT ON THE POPULATION OF WHITE FACE WHISTLING DUCK (*Dendrocygna viduata*) AT BATURIYA WETLANDS GAME RESERVE, JIGAWA STATE, NIGERIA

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ABSTRACT

This study assessed the Impact of Climate Change on the Population of the White-Faced Whistling Duck (WFWD) (***Dendroncygna viduata***) at Baturiya Wetland Game Reserve, Jigawa State, Nigeria. The specific objectives included assessing the changing pattern of rainfall, Relative Humidity, Temperature and Wind Speed from 1993 – 2022 and how those changes impacted on the population of the WFWD in the Reserve. To achieve these, the period covered by the study was purposively grouped into three: the first ten years (1993 – 2002), the second ten years (2003 – 2012) and the last ten years (2013 – 2022). Data were collected based on these groupings. Meteorological records of the four climatic variables from protected and unprotected sides of the Reserve were evaluated. Mean values of these elements from both sides were computed and compared as well as values from among the groupings themselves. The statistical significance of the differences among the four climatic variables were ascertained using the Students` t – test. Results have shown that changes in the mean values of climatic variables in the period under review, had significantly reduced the population of the species from the initial 3, 000 to 2, 350 and to 1, 575 in the first, second and last ten years respectively. The paper concludes that climate change in the Reserve was apparent and its consequences on biodiversity loss was glaring. Large scale investment in afforestation and reforestation projects and full enforcement of environmental laws were some of the major policy recommendations made.

Key Words: Impact, climate Change, White-Faced Whistling Duck, Baturiya wetlands, Game Reserve

INTRODUCTION

The Baturiya Wetlands Game Reserve (BWGR) which was hitherto within the confines of the Sudan Savannah now falls within the Sahel due to environmental degradation and consequences of climate change (Ahmed, *et al.*, 2019; Ahmed *et al.*, 2020). The principal driving forces responsible for this transformation are natural and anthropogenic factors (Muhammad, 2016). This is attested by significant increases in meteorological values of temperature and wind speed as well as decreasing rainfall and relative humidity values with consequent development of aridity, desertification and cyclical draught (NIMET, 2022). These extreme climatic conditions occasioned by deforestation have degraded the environment with concomitant serious losses in agricultural production, biodiversity and natural water supplies (Olaniyan, *et al.*,2015).

In 1976/78, when a large part of Jigawa State was in Sudan Savannah, BWGR was heavily forested with diverse Wildlife resources attracting both local and international tourists. However, with the advent of the transition of Sudan into Sahel Savannah between 1993 and 1995,

ecological degradation wrecked the reserve, rendering its status insignificant (Chiroma, 2023). Studies (Muhammad, 2016 and Hussaini, 2021) have shown that the population of wildlife species in the reserve was decreasing. The situation is so dire that extinction of both forest and wildlife species as well as those that have been endangered or threatened form the central themes of Annual Reports of public and private organizations managing renewable resources across the country. These may not be unconnected with the deteriorating environmental condition posed by changes in climate.

As part of the efforts to fix the degraded reserve, this paper advocates for comprehensive assessment of the extent of changes in climatic variables and how they impact on the population of the wild flora and fauna species in the area. First; it would investigate the changing pattern of rainfall, temperature, R.H. and wind speed from 1993 to 2022 at BWGR and; second, it would assess the impact of these changes on the population of the White Face Whistling Duck (WFWD). This study is restricted to only four climatic variables already highlighted, because they are the main observable and measurable variables that can indicate significant changes in climate (FAO and UNEP, 2013; Zira, 2014 and Muhammad, 2016). Again, the exceptional high sensitivity of WFWD to climatic changes is the principal reason for its selection from among tens of other avifauna species flourishing in the area.

Research Questions

The following research questions were asked:

1. Were there changing pattern of the four climatic variables measured at 10 years interval

between 1993 and 2022 at BWGR?

2. Were there significant impacts of changes in the four climatic variables measured at 10 years' interval between 1993 and 2022 at BWGR on the population of the WFWD at BWGR?

Hypotheses

The following hypotheses were tested:

H_0: There were significant differences among mean values of the four climatic variables measured at 10 years interval (2003 – 2022) at BWGR.

H_1: There were no significant differences among mean values of the four climatic variables measured at 10 years interval (2003 – 2022) at BWGR.

H_0: Changes in climatic variables measured at 10 years interval (2003 - 2022) had significant impact on the population of the WFWD at BWGR

H_1: Changes in climatic variables measured at 10 years interval (2003 - 2022) had no significant impact on the population of the WFWD at BWGR

Climate and Climate Change

Climate is simply the average weather condition of a particular area over a long period of time preferably over 35 years in terms of its rainfall, Relative Humidity, temperature, wind speed and direction, cloud and vegetation cover as well as other Variables of climate (Muhammad, 2016). Climate change on the other hand refers to significant changes in global temperature, precipitation, wind patterns and other measures of climate that occur over several decades or longer (Hussaini, 2021). The changes in climate are attributable directly or indirectly to human activities that alter the global atmospheric composition observable over comparable time period (IPCC, 2017). Besides anthropogenic activities, climate change has been attributed to natural internal and external processes and forces. Simply put, climate change is attributed to anthropogenic and natural causes.

Anthropogenic Factors

These comprise deforestation which completely displace wildlife habitat by

large scale removal of trees and vegetation (Zira, 2014). This invariably denies them food and shelter forcing the affected species to extinction or migration. Repeated application of chemical fertilizers is yet another anthropogenic factor with negative consequence on wildlife population particularly the carnivorous species that occupy the higher tropic level of food chain (Muhammad, 2016). These chemicals often kill insects and small mammals serving as food to the carnivorous species.

Another anthropogenic factor posing serious threats to wildlife population is urbanization. The foremost threat in this aspect is habitat loss and fragmentation (Birdlife, 2017). This stimulates rapid decision to emigrate to a more suitable habitat or at least cope with the new condition (Hussaini, 2020). Moreover, urbanization often change the existing or the remaining ***green areas*** through plantation of non-native plant species, managed lawns, and removal of the mid-story canopy (Birdlife, 2015). Although, the total number of bird species declines once an area is urbanized, many bird species do seem to flourish.

Natural Factors

Drought and high temperature with extreme low humidity are natural factors that can easily lead to forest fires especially in the Sahel and Sub-Sahara Africa. This happens between October and February when uncontrolled bush fire spread rapidly covering long distances and sometimes is only halted by natural barriers like rivers and streams. There is usually delay in vegetation recovery. Studies (Birdlife, 2017) have shown that species that couldn't recover from fire devastation get completely eliminated from the community. Changes in temperature and precipitation is accompanied by changes in forest location, structure, composition and productivity. Thus, climate change can usher in species migration leading to changes in geographical distribution of forest types and new combination of species within the forest (IPCC,2017).

The current global warming induces ice melting at the polar regions causing water flow in Seas and oceans giving rise to increases in water levels. As this continues, the lower coastal regions become prone to flood catastrophe. The rise in sea level is accelerated by excessive evaporation and excess moisture in the atmosphere leading to excessive rainfall. Forest vegetation generally requires certain amount of rainfall during growth period (Birdlife, 2015). When this becomes excessive it leads to poor vegetation density, droughts, as well as loosen species.

Forest vegetation density stabilizes the soil. Negative changes in climate results into low species population, more unregenerate gabs, thereby opening the vegetation to more direct and intense rain drops. Unshielded forces of rain lead to sheet and other form of forest soil erosion, paving way for various forms of environmental hazards to take their turn.

Effects of Climate Change on Biodiversity

A change in climate pattern either to the right or to the left, is always accompanied by corresponding changes in flora and fauna population of the forest ecosystem (IPCC, 2017). This is widely termed biodiversity loss, avifauna species inclusive. Birds population depends on floral composition of the forest which serves as shelter and food and when forest vegetation undergoes changes in composition, depending on the change factor, migration, death or complete species extinction occurs.

Climate Change Impact on Bird Population

Highly sensitive to climate and climatic, birds are pioneer indicators of climate change (Berthold *et al.*, 2014), the quintessential "canaries in the coal mine." As global warming brings about changes in

temperature, moisture and precipitation, as well as extreme climatic and more variations in climate, birds from the Arctic and Antarctic regions are already responding. In future, global warming will also affect birds indirectly through rise in sea levels, changes in fire regimes, vegetation and land use. With a doubling of atmospheric CO_2, climate change could eventually destroy or fundamentally alter 35% of the world's existing land habitats (WWF, 2000). In the Arctic region, where several hundred million of migratory birds' flourish, a doubling of CO_2 suggests the loss of almost half the breeding grounds of 10.4 million geese and 14.5 million waders by 2080-2099. Some Arctic birds will lose more than 90% of their habitat at higher levels of warming (Birdlife, 2015). By 2080s, habitat for migratory birds could be completely destroyed when the temperature increases from 1.5 to 4.2°C particularly in Europe and Mediterranean coastal wetlands (IPCC 2021). Climate change will also cause some of its most serious but least predictable impacts by shifting the timing of natural events and by shifting species geographical distributions. This will re-arrange plant and animal communities and ecosystems, disrupt birds' relationships with predators, competitors, prey and parasites. These changes are expected to alter the makeup and functioning of most, if not all, the world's ecosystems (Root and Hughes, 2015). Evidences have shown that many bird species will not be able to adapt. These timing shifts are a threat when they force birds' life cycles out of synchrony with plants and insects upon which they depend (Birdlife, 2015 and IPCC, 2017). In Europe, some populations of pied flycatchers, which are long-distance migratory birds, have suffered a 90 per cent decline in numbers over the past two decades, an effect strongly linked to their failure to keep pace with climate change. With their insect prey numbers peaking earlier due to warming, but their migration timing unchanged, they no longer arrive at their breeding grounds in time to match peak food supply with peak nestling demands (Both *et al.,* 2016). Thus climatically-forced shifts can harm birds' reproductive success and survival, and could even contribute to the collapse of breeding populations over the long term (WWF, 2000). The mismatch puts serious additional pressure on long-distance migrant birds, which are vulnerable to the summed climatic risk for each habitat used along their migration path (Huntley *et al.,* 2016). Of 119 long-distance migrants studied in Europe, 54 per cent have already shown a sustained, often severe, decline from 1970 to 2000, with climate change implicated as a major contributing factor (Birdlife, 2015).

Climate Change and Extinction of Avifauna Species

Climate change puts many bird species at risk of extinction, even those currently considered safe (Birdlife, 2015); and the stronger the climate change the stronger the risk. With a global mean surface temperature increase of 1-2°C above pre-industrial levels, many unique and threatened ecological systems will be at risk and numerous species will face extinction (Noble *et al.,* 2005).

Risk is dependent on the species. The white face whistling-duck (*Dendrocygna viduata*), like many other bird species in the Wet Tropics of Australia's northeast, is particularly vulnerable. Its suitable habitat would decrease to 63 per cent with less than 1°C of future warming (Hilbert *et al.,* 2004), illustrating why this zone's climate scenario has been called "an impending environmental catastrophe" by Williams *et al.* (2003). Among particularly vulnerable groups -- migratory, Arctic, Antarctic, island, wetland, mountain and seabirds -- heightened impacts are expected. The threat of climate change to migratory birds is equal to the sum of all other human-caused threats combined (Birdlife, 2017) with 84 per cent of migratory bird species 2 facing some type of climate change threat. For example, the Arctic-breeding red- breasted goose, already globally vulnerable, is

expected to lose 99 per cent of its tundra breeding habitat due to climate change (WWF, 2000). Birds that are habitat specialists are at higher risk than generalists (Huntley *et al.,* 2006; RSPB/WWF 2003).

Birds breeding in arid environments (Hussaini, 2021) and those with low population numbers, poor dispersal ability, already poor conservation status, and restricted or patchy habitats or limited climatic ranges are also at elevated risk from climate change (Huntley et al, 2006). The overall extinction risk of climate change to birds is still being quantified.

However, many current projections of climate impacts, including those of the Intergovernmental Panel on Climate Change (IPCC), are likely to be underestimates (Thomas *et al.,* 2004). Most research considers only the direct effects of temperature or precipitation will have on shifting or contracting climatically-suitable ranges. Limiting the number of climate variables used potentially underestimates the risk of key climate change (Muhammad, 2016).

Distributions of birds, like most plants and animals, are limited by climatic factors including temperature, precipitation, and wind. Indeed, climate is one of the most important factors in determining birds' ranges and abundance (Birdlife, 2015). At high latitudes, temperature most influences the number of species found (species richness), while at low latitude, high temperature regions, water-related climate variables are more important (Böhning-Gaese and Lemoine, 2004). "Climate" refers to the aggregate of climatic events over the long term. The effects of climatic on birds are well known (Both, *et al.,* 2016), being both diverse and important. Consequently, birds are very sensitive to changes in climate (Berthold *et al.,* 2004). Compelling evidence shows that birds are responding to climate change, which makes them" pioneer indicators" for changes related to global warming (Berthold *et al.,* 2014).

Changes in Temperature

Temperature affects birds both directly and indirectly. Birds are warm-blooded (endothermic) animals and must maintain constant body temperature. The response of birds to climate change will vary from species to species, depending on how strongly their metabolism reacts to new temperature levels (Root and Hughes, 2015). Climate change will affect temperatures in regions around the globe differently. Higher latitudes (i.e. regions closer to the poles) are generally undergoing more intense changes in temperature, with the Arctic warming almost two times the global average rate over the past few decades (IPCC, 2017), thus habitat loss is expected to be most marked toward the poles (WWF, 2000) as species respond to this change. Where local and regional climates warm due to climate change, bird species are expected to shift their distributions either pole-ward or upward in elevation (in mountainous zones) to maintain their optimum temperatures. Because some species are adversely affected by temperature increases as small as 1°C (Hilbert *et al.,* 2014), they face an uncertain future if they cannot shift their distribution to track their optimum climate envelope.

Changes in Precipitation

Precipitation and moisture are critically important climate variables to birds, and changes are expected to affect birds both directly and indirectly. Some species, including inland water birds such as ducks, are highly dependent on precipitation to sustain their wetland habitats. Consequently, precipitation reductions have major implications for these species. And although warming is likely to be the more critical climatic variable for bird species at higher latitudes, at the tropics precipitation timing and intensity may be more critical (Root and Hughes, 2005). Periods of low or zero rainfall tend to be linked to reduced bird populations because these dry spells reduce bird food sources,

such as insects and fruit (Williams, 2013). Precipitation, along with temperature, is also especially likely to influence the behaviour of migratory birds. It is expected to affect their decision to depart for migration indirectly by acting on food availability and birds' consequent ability to build up energy reserves. Drought in critical stopover areas for migratory birds affects their ability to refuel on water and prey before crossing barriers such as deserts (Bairlein and Hüppop, 2014). Changes in snowfall will also affect birds in mountain habitats if these species depend on areas of freshly melted snow to keep the ground wet and rich in insect life (Inouye *et al.*, 2000).

Habitat Changes

With a doubling of CO_2, climate change could eventually destroy 35 per cent of the world's existing terrestrial habitats (WWF, 2000). Birds' habitats will be altered through changes in sea level, fire regimes, vegetation and land use (Böhning-Gaese and Lemoine, 2014; IPCC, 2021b). Over the last 100 years, the global sea level has risen by about 10-25 cm, depending on location. As noted above, rising sea levels can combine with increased wave activity during storms to inundate, erode or alter important bird habitat.

Sea level rise is expected to inundate lowland coastal bird habitats around the world, including marshes. One important effect will be "coastal squeeze". As rising sea levels inundate existing estuaries and deltas, hard sea defences and agricultural or urban land will effectively form barriers against the natural retreat of these habitats up the shore (i.e., further inland; UNEP, 2005). This combination of rising sea level and coastal squeeze could permanently inundate mudflats, severely impacting wildfowl and wader species (Nobel, *et al.*,2005). As noted above, rising sea levels will combine with tidal surges to threaten the nests and young of birds on low-lying islands or near the shore. By increasing the length and intensity of summer drought in many parts of the world, climate change has increased the susceptibility of ecosystems to fires. Fire, and fire frequency has increased (IPCC 2021), destroying forest bird habitat. Climate change is also expected to cause major shifts in vegetation further reducing bird habitat. Climate change could also prompt shifts in land use by humans, such as agriculture change, which will also impact on birds.

The White-Faced-Whistling Duck

The name White-Faced Whistling Duck (WFWD) comes from the bird's white face and its characteristic three-note whistle. The beak is black, while the throat is white. The back of the head and neck are black. Legs and feet are grey. The lower neck, chest and back are rust- coloured, while the sides are narrowly barred black and white. The upper part of young ones is mostly dark brown while creamy yellow dominates the downside with patches of creamy spots on the back. They are long-legged and long-necked ducks. The WFWD or tree ducks of the genus Dendrocygna They include the following: Spotted Whistling Duck D. guttata, Eyton's D. eytoni, Wandering D. arcuata, Fulvous D. bicolor,Cuban D. arborea, Javan or Lesser D. javanica, and Red-billed Whistling Duck D. autumnalis. White-faced whistling ducks average is 15 to 19 inches in length and weigh between 1 to 1 ½ pounds. Males are usually smaller than females (Birdlife, 2015).

The WFWD shows more primitive features than other living water-fowl. These features include a pan tropical and sedentary distribution, a single annual body moult, monomorphism and a long-standing pair bond, and the participation of both sexes in nest-building, incubation and defence of nest and young (Kear 1990).

White-face Whistling ducks mature during their first year, and most species inhabit low latitudes where seasonal changes in day length can be of little consequence in timing the onset of the breeding season. The White-face Whistling-duck is geographically one of the most widespread

of waterfowl species, while the Fulvous is listed as among the world's rarest birds.

White-faced Whistling Duck *Dendrocygna viduata* has a wide breeding range that extends over sub-Saharan Africa and large areas of South America. It is gregarious and can congregate in thousands in suitable wetlands (Brown et. al. 1999). It is globally assessed as Least Concern (LC) according to the IUCN Red List (Bird Life International 2017).

In Africa it has regular movements of over 400 km, probably in response to rainfall or drought, and in north-east Africa it has been recorded at Wadi Haifa in Sudan, close to the Egyptian border.

Habitat

White-faced whistling ducks live in a variety of wetland areas. They prefer bodies of freshwater in open areas. They sometimes live in very small bodies of open water.

Gestation

The breeding season of White- (faced whistling ducks is during the rainy season in the wild, in captivity, they normally breed in spring when it gets warmer. These ducks can lay as much as 16 eggs. Hatching time is 26 – 28 days. Ring the ducklings when they are 17 days old with rings of 11 millimetres. Their Litter is Clutch: 4-13 eggs

BEHAVIOR

The White-faced whistling duck is highly social with flocks often numbering in the hundreds. In the non-breeding season, the birds roost on banks, preening themselves and each other. Mutual preening is highly developed with this species. Foraging is done primarily at night. Normally this duck does not migrate, but flocks will travel considerable distances to find suitable feeding areas. Their flight is slow and heavy with rounded wings. They swim and dive well. These ducks are very tame and do not disperse when hearing gunshots (Birdlife, 2015).

Reproduction

Mutual preening is an important part of pair-forming and pair-maintaining behavior for White-faced whistling ducks. The nest site is a depression in dry ground or in reed beds over water. Few or no feathers are present in the nest. Incubation is performed by both sexes. The ducklings are kept hidden among water lilies and reeds.

Wild Diet

These ducks are primarily night feeders, during the day the birds roost near the water, often in flocks of several hundred. Mutual preening plays an important part in the formation of pairs and maintenance of bonds. and the mainstay of their diet is vegetation such as grass, seeds and rice, as well as aquatic invertebrates. (Birdlife, 2017) They are particularly fond of seeds and fruits of water lilies. White-faced whistling ducks obtain their food by dabbling and diving.

MATERIALS AND METHODS

The Study Area

The Baturiya Wetlands Game Reserve (BWGR) derived its name from the neighbouring community of *Baturiya*. An area very conducive for western tourists. *Baturiya* in Hausa language means *a lady from Europe*. This dates back to 300 to 400 years when the area was a camping ground for European tourists. BWGR is sometimes referred to as Hadejia Wetlands Game Reserve (HWGR). It is a natural wetland that falls within the confines of Sudano-Sahelian parts of Jigawa State. Specifically, it lies between latitudes 12^0 30^1 and 12^0 40^1 degrees North and longitudes 10^0 05^1 and 10^0 35^1 degrees East. It occupies the West and Eastern sides of river Hadejia, sharing boundaries with Auyo, Kirikasama and Guri Local Government areas of the State. The reserve is internationally recognized as a hot spot for the conservation of flora and fauna species (Chiroma, 2019). It covers a total land area of $320km^2$ including the buffer zone. Ponds and flooded lands that

are seasonally fed by rivers Kafin Hausa and Katagum form the major drainage feature of the area. These water bodies provide favourable habitat for a great variety of wildlife resources, particularly to the migratory and local water birds. Historical records have shown that in the early 70s, the area was inhabited by numerous and varied species of wild resources besides considerable number of Ponds and Lakes that were rich in fish, crocodiles and other wild aquatic resources. It is for this reason that the then emir of Hadejia decided to organize an annual fishing festival at the site. While attending one of such festivals, Alhaji Audu Bako, the then Governor of Kano State became fascinated and was attracted by the population and species of wildlife resources flourishing in the area. Consequently, he directed the Forestry Department to establish a Game Reserve Baturiya. Both the establishment and the first survey of the reserve were accomplished in 1975, re-surveyed in 1980 and officially Gazetted as a Game Reserve in 1985. As part of the efforts to manage the reserve sustainably, the Baturiya Wetlands Conservation Project was lunched and started as a partnership between the governments of Borno, Bauchi, and Kano States, the Nigeria conservation foundation (NCF) and Royal society for the protection of Birds. (Birdlife, 2017). The project was established in 1987 with the following objectives. To:

(i) Explore appropriate land use options for the water resources of the Hadejia wetlands for the benefit of wild life and human activities.

(ii) Monitor wildlife resources throughout the project, especially migrants‟ water birds whose movement depend on the seasonal variations in water cover.

(iii) Develop conservation education and public awareness programs for communities in the area.

(iv) assist state Wildlife Departments by training both staff in the Hadejia wetland and the overseers.

The project aims to protect migratory bird species which are threatened by habitat destruction pollution and hunting. The project has been under the management of the World Conservation Union (IUCN) since 1990, and has increasingly been concerned with the maintenance of the economic and ecological function of the wetland in particular and the promotion of sustainable development in the Kumadugu-Yobe basin in general (Muhammad, 2016). Many parts of the area covered by Baturiya wetland conservation project are suffering from land degradation. Large areas exist with only two or three trees per hectares and supplying needs for fuel wood is a serious problem in many villages.

Instrument of Data Collection

Data were collected using a structured questionnaire administered to the staff of the Meteorological Unit of the BWGR. Data collection was accomplished at ten years interval, beginning from 1993 – 2022, covering variables including the mean population of the WFWD, rainfall, temperature, relative humidity and wind speed. Mean values of the same climatic variables within the same time frame were compared with those of the National Meteorological Agency of Nigeria (NIMET) as control.

Tool for Data Analysis

The principal analytic tool employed in testing the significance of the differences among mean values of the four climatic variables and the population of the WFWD at BWGR at 10 years interval was students` t-test. The outline of model is given below –

$$t = \frac{\overline{x_1} - \overline{x_2}}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

Where:

t = Students` t-test result computed from: BWGR

$\overline{x_1}$ = Mean values of the four climatic variables at 10 years at BWGR

$\overline{x_2}$ = Mean value of the four climatic variables at 10 years interval from NIMET station

s_1^2 = Variances of BWGR data from mean

s_2^2 = Variances of NIMET data from the mean

n_1 = Number of meteorological data sampled from BWGR at 10 years interval

n_2 = Number of meteorological data sampled from NIMET at 10 years interval

The degree of freedom (df) from error acceptable at 5% probability is given by

df = n_1 + n_2 - 2……. (ii)

Where; df = degree of freedom n_1 and n_2 have already been defined in equation 1 above.

RESULTS

Table 1.0 summarizes the changing pattern of Climatic Variables from 1993 to 2022 at BWGR

S/N	Climatic Variable	Mean Changes Observed		
		1993 – 2002	2003 - 2012	2013 – 2022
1	Rainfall (mm)	241.84	231.64	222.38
2	Relative Humidity (%)	28.42	23.40	18.25
3	Temperature (^{O}C)	22.63	25.63	28.36
4	Wind Speed (km/hour)	01.13	02.95	O5.44

Source: Field Survey, 2023

It is evident from the Table 1.0 above that the mean values of rainfall and relative humidity have been decreasing as oppose to the increasing values of temperature and wind speed within the period under investigation. This simultaneous ***increas***e and ***decreas***e in the mean values of the four climatic variables had consequential effects on the specie`s population. For that reason, there was need to analyse the changing pattern of those climatic variables in the first, second and the last ten years and how they impacted on the population of WFWD.

The Impact of the changing pattern of the four climatic variables on the population of WFWD in the First 10 years at BWGR

Table 2.0 summarizes the mean values of the four climatic variables at BWGR and NIMET in the first ten years. When compared closely, it was observed that the mean values of rainfall, R.H., temperature and wind speed at BWGR were ecologically more favourable than those of NIMET. Though numerical differences between mean values of the individual climatic variables in the two locations were computed, those differences were not significant and thus didn't make any significant impact on species population. Thus, the mean population of 3000 remained unaffected.

Table 2.0 the impact of the changing pattern of the four Climatic variables on the population of WFWD from 1993 - 2002 at BWGR

Climatic	Difference between	Mean population

Variable	Mean Value (BWGR)	Mean Value (NIMET)			WFWD
			mean values	%	3, 000
Rainfall(mm)	241.84	238.38	03.46	0.72	**3, 000**
R. H. (%)	28.42	26.68	1.74	3.16	**3, 000**
Temperature (^{O}C)	22.63	25.67	-3.04	- 6.29	**3, 000**
Wind Speed (km/hr)	01.13	2.60	-1.47	- 39.41	**3, 000**

Source = Field Survey, 2023

The impact of the changing pattern of the four climatic variables on the population of WFWD in the Second 10 years at BWGR

It was observed from Table 1 that there were differences between average values of the corresponding climatic Variables in the first and second ten years at BWGR. Specifically, results have indicated decreases in the mean values of rainfall from 241.84 mm to 231.64 mm in the first and second ten years respectively. Similarly, R. H. values decreased from 28.42 % in the first ten years to 23.40% in the second ten years. However, temperature increased from 22.63 ^{O}C to 25.63 ^{O}C, and in the same manner, wind speed also increased from 01.13 km/hr to 02.13 km/hr within the same period (Tables 2.0 and 3.0). All the differences among the corresponding climate elements in the first and second ten years were statistically significant (Table 5.0). It was evident that those opposing and unfavourable ecological conditions had significant adverse effect on the population of the species, reducing its magnitude to 2, 350 from the initial 3,000. Thus, numerically, there was a difference of 650 WFWD or 12.15% population reduction between the first and the second ten years intervals. That difference was significant at 5%. On the basis of this therefore, the null hypotheses which postulated significant variability among climatic elements and their significant impact on the population of the species were accepted (vide Tables 5.0, 6.0 and 7.0).

Table 3.0 the impact of the changing pattern of the four Climatic variables on the population of WFWD from 2003 - 2012 at BWGR

Climatic Variable	Mean Value (BWGR)	Mean Value (NIMET)	Differences between		Mean Population WFWD
			mean values	%	2, 350
Rainfall(mm)	231.64	227.83	03.81	01.47	**2, 350**
R. H. (%)	23.40	26.68	03.28	06.55	**2, 350**
Temperature (^{O}C)	25.63	29.67	- 04.04	- 07.31	**2, 350**
Wind Speed (km/hr)	02.13	02.95	- 0.82	- 16. 14	**2, 350**

Source = Field Survey, 2023

The impact of the changing pattern of the four climatic variables on the population of the WFWD in the last 10 years (2013 – 2022) at BWGR

Same trend of changes has been observed as in the last 10 years (Table 3.0). Mean values of rainfall and R.H. kept decreasing as oppose to the increasing mean values of temperature and wind speed when compared with the corresponding values in the second ten years (Table 2.0). Here again, differences between individual values in the second and the last ten years were significant (Table 5.0). In the same manner, the inverse relationship between the two pairs of climatic variables impacted negatively on the population of the WFWD,

reducing it from 2,350 to 1, 575 (Table 4.0). in the second and last ten years respectively. The difference of 775 WFWD computed between the mean populations of both periods was also significant at 5%. In other words, the changes in climatic variables at this stage led to significant reduction in the population of the species by 19.75% (Tables 6.0 and 7.0). All the null hypotheses were accepted for reasons already highlighted.

Table 4.0 impact of the changing pattern of the four climatic variables on the population of WFWD from 2013 – 2022 at BWGR

Climatic Variable	Mean Value (BWGR)	Mean Value (NIMET)	Differences		Mean Popula WFWD
			b/w mean values	%	1, 575
Rainfall(mm)	222.38	220.55	01.83	0.41	1, 575
R. H. (%)	18.25	23.95	05.70	13.51	1, 575
Temperature(^{0}C)	28.36	32.15	- 03.79	- 06.26	1, 575
Wind Speed (km/hr)	05.44	06.11	- 0.67	- 05.80	1, 575

Source = Field Survey, 2023

Table 5.0 Test of Statistical significance of the differences among mean values of climatic variables at 10 years' interval (2003 – 2022) at BWGR

Climatic Variable	Mean Values		Variances		DF	LOS	t -cal	t - tab	H_0
	2003 – 2012	2013 - 2022	2003 - 2012	2013 – 2022					
Rainfall (mm)	**231.64**	**222.38**	**8.3256**	**0.5418**	**18**	**0.05**	**3.1097**	**2.1010**	**Accepted**
Relative Humidity (%)	**23.40**	**18.25**	**0.7399**	**0.2379**	**18**	**0.05**	**5.2083**	**2.1010**	**Accepted**
Temperature (°c)	**25.63**	**28.36**	**0.4388**	**0.5132**	**18**	**0.05**	**2.7980**	**2.1010**	**Accepted**
Wind Speed (Km/hour)	**02.95**	**05.44**	**0.0747**	**0.3114**	**18**	**0.05**	**4.0071**	**2.1010**	**Accepted**

Source = Field Survey, 2023

Key: DF = Degree of Freedom, LOS = Level of significance, t – Cal = t – Calculated, t – tab = t – Tabulated H_0 = Null Hypothesis

Table 6.0 Test of Statistical significance of the impact of changes in climatic variables on the population of the WFWD in the first and second ten years (1993 – 2012) at BWGR

Mean Population		Variances		DF	LOS	t -calculated	t - tabulated	H_0
1993 – 2002	2003 – 2012	1993 - 2002	2003 - 2012					
3,000	**2, 350**	**11.9**	**3, 075**	**18**	**0.005**	**11.70**	**2.1010**	**Accepted**

Source = Field Survey, 2023

Table 7.0 Test of Statistical significance of the impact of changes in climatic variables on the population of the WFWD in the second and the last ten years (2003 – 2022) at BWGR

Mean Population		Variances		DF	LOS	t -calculated	t - tabulated	H_0
2003 – 2012	2013 – 2022	2003 - 2012	2013 - 2022					
2, 350	**1, 575**	**3, 075**	**1, 290.9**	**18**	**0.005**	**11.73**	**2.1010**	**Accepted**

Source = Field Survey, 2023

DISCUSSIONS

The results confirmed a number of environmental degradation bedevilling the Baturiya Wetland Game Reserve. The decreasing values of rainfall and Relative Humidity posed by deforestation were the major factors responsible for increasing aridity, cyclical draught and vegetational transformation widely reported by NIMET in 2022. What were the implications of the decreasing values of both climatic variables on the population of WFWD at BWGR? Many works point to the fact that decreasing values of rainfall and extreme low humidity increases the chances for wild bush fires and fire frequency which destroys wildlife habitat avifauna inclusive (IPCC, 2021). A habitat that is destroyed or severely damaged cannot provide the basic habitat components needed for survival. Starvation eventually sets in since there won't be adequate food and water supplies needed to sustain the population. WFWD are highly dependent on moisture availability and high Relative Humidity to sustain their wetland habitat. This agrees with Williams, *et. al.* (2013) findings that periods of low Rainfall and R.H. significantly reduces bird population due to reduced birds' food sources such as insects and fruits.

On the contrary, results indicated increasing values of temperature and wind speed across the reserve. The implication here also is that the WFWD will still have to grapple with habitat loss or damage. With continuous rise in surface temperature of just 1 – 2^0C, many unique ecological entities including wetlands will be heavily degraded (Birdlife, 2015). Eventually, death will overtake the bulk of the population since the species doesn't migrate. This explains significant reduction in the population of the species at various intervals studied. The high wind speed was attributed to high scale deforestation that wrecked the reserve. Trees sway in the wind and break it, absence of which exposes the habitat of the WFWD to direct impact of wind, rainfall and solar radiation. These conditions often lead to death or complete extinction of the species.

CONCLUSION

Evidences of climate change at BWGR were real and irrefutable. The consequences were manifold: increasing values of temperature and wind speed as well as decreasing values of rainfall and relative humidity ushered in unfavourable environmental conditions such as aridity, draught, desertification and vegetational changes with the resultant loss of biodiversity, agricultural output and water supplies. These problems put together wrecked the Reserve and in effect, it is no longer attracting tourists local or international.

RECOMMENDATIONS

There is a need to invest heavily in climate migration programmes such afforestation and reforestation projects, sand dune fixation and stabilization programmes, regreening urban and rural settlements, erosion, draught and flood control projects. Appropriate environmental laws should be enacted and be enforced to protect the already degraded environment.

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TEMPORARY AND SPATIAL VARIABILITY IN MICROALGAE COMMUNITY STRUCTURE IN RELATION TO ENVIRONMENTAL VARIABLES IN NSIT UBIUM RIVER.

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ABSTRACT

This study investigated the temporal and spatial variability in microalgae community structure of Nsit Ubium River, with a view to determine how its ecological dynamics are influenced by environmental variables. Two key stations: Inyang Udo Nsinia Stream (Station 1) and Ikot Okobo Stream (Station 2) were studied over six months in wet and dry seasons. Spatial grid sampling, species identification and physicochemical variables collected and analysed using standard procedures. A total of 56 algal species from six orders were identified, with Bacillariophyta dominating both stations. Distinctive spatial patterns in algal occurrences, with variations in Bacillariophyta, Dinoflagellates, Chlorophyta, Euglenophyta, Cyanophyta, and Glaucophyta were observed across the two stations. The study also presents percentage occurrences of identified algal orders and physicochemical parameters of the river. The rich biodiversity of Nsit Ubium River calls for extended sampling durations and dissolved oxygen measurements in future research. Long-term monitoring programs and collaboration among relevant stakeholders are needed to effectively integrate conservation initiatives into environmental management plans for the preservation of Nsit Ubium River's unique ecosystem health.

Keywords: Nsit Ubium River, Microalgal communities, Temporal and spatial variability, Ecological dynamics, Environmental variables.

INTRODUCTION

Microalgae are vital components of aquatic ecosystems, contributing significantly to primary production and nutrient cycling (Reynolds, 2006). These microscopic, photosynthetic organisms form the base of the aquatic food web and play a critical role in regulating water quality and overall ecosystem health (Sharma *et al*., 2020). The composition and structure of microalgae communities are influenced by various environmental variables, including temperature, pH, nutrient levels, and light availability (Huisman *et al*., 2002).

Environmental variables such as temperature can have a profound impact on microalgae growth and distribution. Studies have shown that temperature influences the metabolic rates of microalgae, affecting their growth rates and seasonal dynamics (Litchman *et al*., 2010; Van Donk and Hessen, 1993). Changes in temperature can lead to shifts in the dominance of specific microalgae species, which, in turn, can have cascading effects on higher trophic levels within aquatic ecosystems (Paerl and Huisman, 2008).

pH levels in aquatic environments also play a crucial role in shaping microalgae communities. Certain microalgae species are more adapted to specific pH ranges, and variations in pH can lead to changes in species composition (Brett *et al*., 2012; Yang *et al*., 2018). Altered pH conditions can favor the growth of some species over others, potentially influencing the overall diversity and stability of the microalgae community.

Nutrient availability, particularly nitrogen and phosphorus, is another key factor influencing microalgae community structure. High nutrient levels, often associated with

anthropogenic inputs, can lead to eutrophication, causing shifts in microalgae composition and potentially resulting in harmful algal blooms (HELCOM, 2018; Smith *et al*., 1999). Understanding the dynamics of nutrient-driven changes in microalgae communities is essential for managing and mitigating the impacts of eutrophication.

Light availability is critical for microalgae as they rely on photosynthesis for energy production. Light intensity, duration, and spectral quality can affect the growth and distribution of microalgae species (Hessen *et al*., 2006; Cloern, 1999). Seasonal and spatial variations in light conditions in aquatic ecosystems can lead to changes in microalgae community structure.

While numerous studies have explored the relationship between microalgae communities and individual environmental variables, there is a growing need to investigate the combined effects of multiple variables on microalgae community structure (Lurling *et al*., 2013). Additionally, spatial and temporal variations in microalgae communities within aquatic ecosystems have received less attention, despite their ecological importance (Reynolds *et al*., 2002; Sinha *et al*., 2017).

structure.

MATERIALS AND METHODS

Study Area

Ikot Okobo river is a significant water body located in Nsit Ubium Local Government in Akwa Ibom State, Nigeria. Positioned within the Niger Delta region, it is a tributary of the Cross River, ultimately draining into the Gulf of Guinea. This meanders through the lush, tropical landscape of southern Nigeria, traversing an area of ecological and cultural importance. The river's size and extent can vary seasonally, influenced by rainfall patterns and runoff. During the rainy season, Ikot Okobo river can expand in width, creating an intricate network of waterways through the surrounding wetlands and forests. The region's topography is characterized by low-lying floodplains and swamps, with the river serving as a vital component of the local hydrology. Ikot Okobo river is known for its rich biodiversity and diverse microalgae communities. The river's environmental features, including water quality, flow dynamics, and nutrient levels, play a crucial role in shaping the spatial and temporal variations in microalgae community

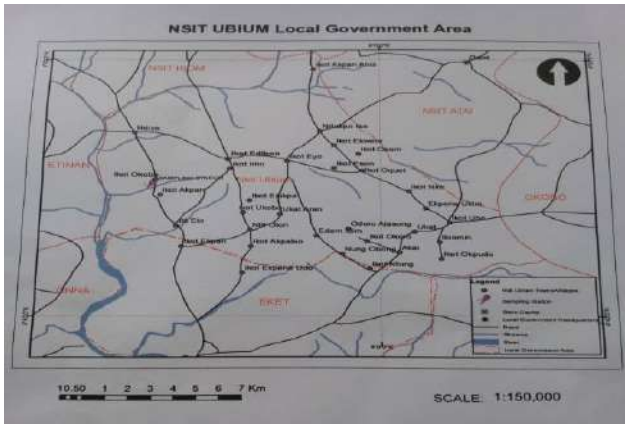

Figure 1: Map of Nsit Ibom Local government Area Showing Inyang Udo Nsinia Stream

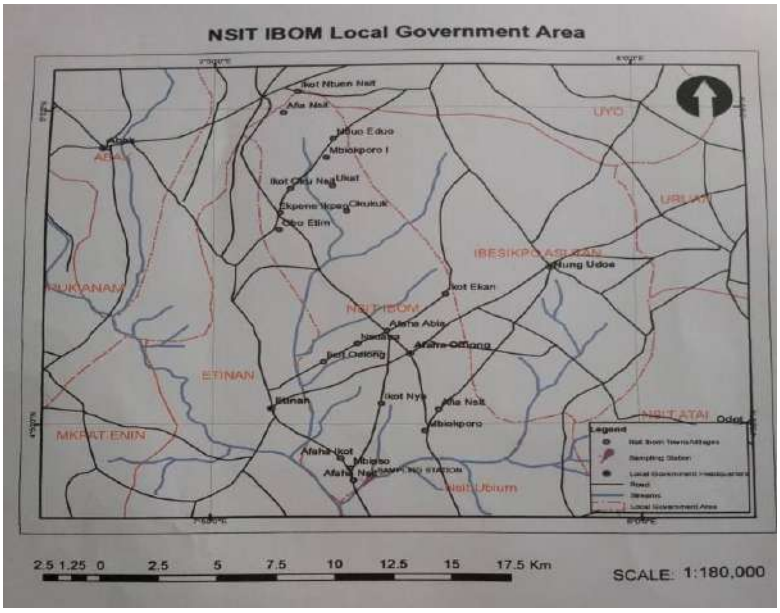

Figure 2: Map of Nsit Ubium Local Government Area showing ikot Okobo Stream

Site Selection

Sampling sites were selected along the river. Sites was done to strategically capture spatial and temporal variability. Factors considered include different river segments, gradients, proximity to potential nutrient sources, and areas with varying light availability due to natural features or human influences.

Spatial Grid

To systematically cover the study area, a spatial grid was established. The river is divided into sampling sections, and specific GPS coordinates was used to identify each sampling location. This grid ensures that data collection is representative of the entire river system.

Seasonal Sampling

Given the seasonal dynamics in Nsit Ubium River, sampling was conducted throughout from May to October (6 months) to account for temporal variations with a month interval. Multiple sampling campaigns was carried out during different seasons, with a focus on both wet and dry periods. Seasonal sampling captures changes in flow rates, nutrient concentrations, and light availability.

Water Quality Measurements

Prior to microalgae sampling, water quality parameters are measured at each site. These include temperature, pH, dissolved oxygen, turbidity, and nutrient levels (nitrogen and phosphorus). Water quality data are essential for understanding the environmental context of the microalgae communities.

Microalgae Sampling

Water samples were collected into 38cl of clean water bottles. Microalgae samples were collected using a combination of methods.

Water Column Sampling: Vertical profiles of the water column were obtained using a

plankton net or sediment sampler to capture microalgae suspended in the water at different depths.

Benthic Sampling: Sediment samples were collected to assess benthic microalgae. Benthic samples were obtained using corers or sediment grab samplers.

Sample Preservation

Microalgae samples were preserved using appropriate fixatives Lugol's iodine to immobilize and preserve the organisms without disrupting their cellular structure. Proper sample preservation is crucial for accurate species identification and enumeration.

Laboratory Techniques and Methods for Analyzing Microalgae Samples

Sample Preparation

Upon returning to the laboratory, microalgae samples (both planktonic and benthic) are carefully prepared. This involves concentrating planktonic samples and separating benthic microalgae from sediment matrices.

Enumeration of Microalgae

To determine the abundance of microalgae, Sedgwick-Rafter counting chambers are used. A known volume of the concentrated sample is placed on a microscope slide, and microalgae cells are counted under a microscope.

Species Identification

Identification of microalgae species is a crucial part of the analysis. Microscopic examination is used to assess the morphological characteristics of individual cells or colonies. Specialized taxonomic keys and reference materials are consulted to identify species. In the case of benthic microalgae, sediment samples are processed to separate the microalgae from the sediment particles. This may involve centrifugation, decantation, or sieving, depending on the sediment characteristics.

Chlorophyll-a Analysis

Chlorophyll-a is often used as a proxy for microalgae biomass. It is extracted from the microalgae samples using organic solvents acetone. The extracted chlorophyll-a is then quantified using spectrophotometry or fluorometry.

Microscope Analysis

Microalgae cells are carefully examined under a light microscope or inverted microscope. Various microscope objectives (e.g., 40x, 100x) are used to observe cells at different magnifications. The microscope is equipped with a camera for image capture and documentation

Data Integration

Data from water quality measurements and microalgae sampling were integrated to assess the relationship between environmental variables (e.g., nutrient levels, light availability, temperature) and microalgae community structure. Statistical analysis, regression models, were applied to determine correlations and patterns. Regression analysis, including linear regression and multiple regression, is used to model the relationship between specific environmental variables (e.g., nutrient concentrations, light availability, temperature) and microalgae abundance or diversity.

RESULTS

Algal Occurrence

In this study a total of 56 algal species belonging to 6 orders were identified in both stations, 32 identified from Station 1 and 30 identified from station 2. Identified orders were Bacilliariophyta, Dinoflagellates, Chlorophyta, Euglenophyta, Cyanophyta

Glaucophyta. In all, Bacilliariophyta was found more abundant across the two stations.

Table 1: Table showing all species identified at both stations

S/N	Division	*Species*	Station 1	Station 2
	Bacillariophyta	*Pinnularia borealis*	1	-
	Bacillariophyta	*Pinnularia brebissonii*	1	-
	Bacillariophyta	*Pinnularia* sp.	-	1
	Bacillariophyta	*Nitzschia pusilla*	1	-
	Bacillariophyta	*Nitzschia umbonata*	-	1
	Bacillariophyta	*Kobayasiella parasubtilissima*	-	1
	Bacillariophyta	*Rhopalodia gibba*	1	-
	Bacillariophyta	*Rhopalodia* sp.	3	4
	Bacillariophyta	*Rhopalodia operculata*	1	-
	Bacillariophyta	*Rhopalodia brebissonii*	-	1
	Bacillariophyta	*Diploneis* sp.	1	1
	Bacillariophyta	*Nitzschia nana*	1	-
	Bacillariophyta	*Gomphonema* sp.	2	-
	Bacillariophyta	*Cocconeis placentula*	-	1
	Bacillariophyta	*Nitzschia angustata*	-	1
	Bacillariophyta	*Navicula* sp.	1	-
	Bacillariophyta	*Achnanthidium exiguum*	1	-
	Bacillariophyta	*Navicula lanceolata*	1	-
	Bacillariophyta	*Brachysira* sp.	1	-
	Bacillariophyta	*Frustulia rhomboid*	1	-
	Bacillariophyta	*Frustulia quadrisinuata*	-	1
	Bacillariophyta	*Frustulia saxonica*	-	1
	Bacillariophyta	*Frustululia crassinervia*	1	-
	Bacillariophyta	*Frustulia magaliesmontana*	-	1
	Bacillariophyta	*Frustulia vulgaris*	-	1
	Bacillariophyta	*Frustulia undosa*	-	1
	Bacillariophyta	*Craticula halophile*	-	1
	Bacillariophyta	*Eunotia incise*	-	1
	Bacillariophyta	*Actinella brasiliensis*	1	-
	Bacillariophyta	*Eunotia bilunaris*	1	-
	Bacillariophyta	*Fragilariforma* sp	1	-
	Bacillariophyta	*Diatoma vulgaris*	-	1
	Bacillariophyta	*Tabellaria* sp.	1	-
	Bacillariophyta	*Tabellaria fenestrate*	1	-
	Bacillariophyta	*Diadesmis confervacea*	-	1
	Bacillariophyta	*Fragilaria* sp	1	-
	Dinoflagellates	*Amphidinium* sp	1	-
	Chlorophyta	*Cosmarium per maculatum*	-	1
	Chlorophyta	*Euastrum* sp.	1	-
	Chlorophyta	*Spirogyra* sp	1	2

	Chlorophyta	*Closterium moniliferum*	1	-
	Chlorophyta	*Closterium limneticum*	-	1
	Chlorophyta	*Geminella* sp.	-	1
	Chlorophyta	*Cladophora glomerata*	1	-
	Euglenophyta	*Phacus pleuronectes*	1	-
	Euglenophyta	*Phacus curvicauda*	-	1
	Euglenophyta	*Phacus orbicularis*	-	1
	Euglenophyta	*Phacus acuminatus*	1	-
	Euglenophyta	*Phacus* sp.	1	-
	Euglenophyta	*Euglena gracilis*	-	1
	Cyanobacteria	*Calothrix* sp.	-	1
	Glaucophyta	*Glaucocystis* sp.	-	1
TOTAL			32	30

Table 2: Table of Study stations showing the Percentange occurances of identified Algal orders

Order	Station 1	Station 2	Percentage occurrence (Station 1)	Percentage occurrence (Station 2)
Bacilliariophyta	24	20	75	66.67
Dinoflagelletes	1	-	3.125	-
Chlorophyta	4	5	12.50	16.67
Euglenophyta	3	3	9.37	10.00
Cyanophyta	-	1	-	3.33
Glaucophyta	-	1	-	3.33
TOTAL	32	30		

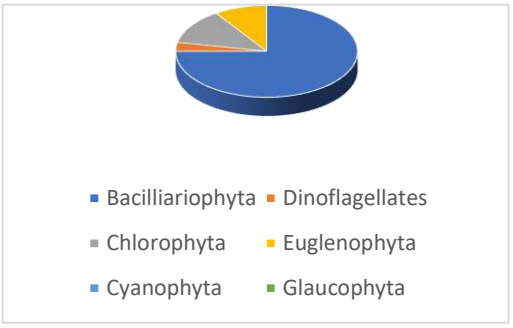

Figure 1: Percentage Occurrence of Algal orders in Station 1

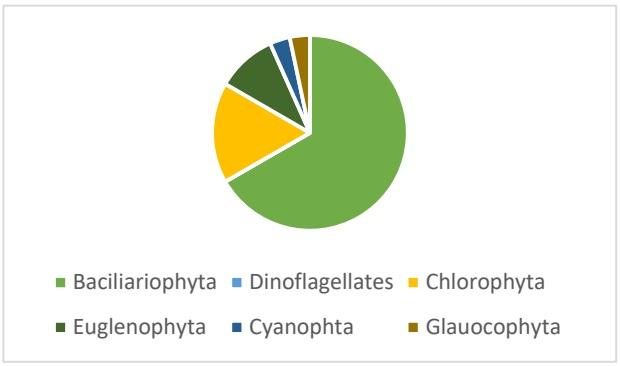

Figure 2: Percentage Occurrence of Algal orders in Station 2

Table 3: Physicochemical parameter of the Study stations

Physicochemical parameters	Station 1	station 2
pH	5.3	5.2
DC (Us/cm)	9	11
TDS (Mg/l)	4.5	5.5
DO (Mg/l)	N/D	N/D
BOD (Mg/l)	N/D	N/D
COD (Mg/l)	10.00	28.00
SO4 (Mg/l)	0.83	7.07
PO4 (Mg/l)	0	0
Ca (Mg/l)	1.60	6.41
Fe (Mg/l)	0.38	0.51
Zn (Mg/l)	0.001	0.001
Cu (Mg/l)	N/D	0.001
Pb (Mg/l)	0.04	0.04
TPH (Mg/l)	N/D	N/D
THC (Mg/l)	N/D	N/D
O/G (Mg/l)	N/D	N/D

KEY: N/D- Not Detected.

Figure 3: Microgram of algal species identified in the 2 stations

I: Pinnularia brebissonii (400x), II: *Pinnularia borealis* (400x), III: *Pinnularia* sp. (400x)

IV: *Nitzschia pusilla* (400x), V: *Nitzschia umbonata*(400x); VI: *Kobayasiella parasubtilissima*(400x); VII: *Rhopalodia gibba* (400x)*; VIII: Rhopalodia* sp. (400x); X: *Rhopalodia acuminate* (400x); X: *Rhopalodia* sp. (400x); XI: *Rhopalodia* sp. (400x); XII: *Rhopalodia* sp. (400x); XIII: *Rhopalodia operculata* (400x)*; XIV: Rhopalodia* sp. (400x)*; XV: Rhopalodia* sp. (400x); XVI: *Rhopalodia brebissonii* (400x); *XVII: Diploneis* sp. (400x); XVII: *Diploneis* sp. (400x); XVIII: *Nitzschia nana* (400x); XIX: *Gomphonema* sp. (400x); XX: *Cocconeis placentula* (400x); XXI: *Nitzschia angustata* (400x); *XXII: Navicula* sp. (400x)**; XXIII:** *Achnanthidium exiguum* (400x)*; XXIV: Navicula lanceolata*(400x)*; XXV: Brachysira* sp. (400x)*; XXVI: Frustulia rhomboid* (400x); XXVII: *Frustulia quadrisinuata* (400x); XXVIII: *Frustulia saxonica* (400x); XXIX: *Frustululia crassinervia* (400x); XXX: *Frustulia magaliesmontana* (400x)*; XXXI: Frustulia vulgaris* (400x); XXXII: *Frustulia undosa* (400x); XXXIII: *Craticula halophile* (x400); XXXIV: *Eunotia incise* (400x); XXXIV: *Actinella brasiliensis* (400x)*; XXXV: Eunotia bilunaris*(400x); XXXVI: *Amphidinium* sp. (400x); XXXVII: *Fragilariforma* sp.*; XXXIX: Diatoma vulgaris; XL: Tabellaria* sp.*; XLI: Tabellaria fenestrate* (400x)*; XLII: Diadesmis confervacea* (400x); XLIII; *Gomphonema* sp.; XLIV: *Cosmarium per maculatum* (400x)*; XLIV: Euastrum* sp. (400x); XLV: *Spirogyra* sp. (400x); XLVI: *Spirogyra* sp. (400x): XLVII: *Spirogyra* sp. (400x); XLVIII: *Fragilaria* sp. (400x); XLIX: *Closterium moniliferum* (400x)*; L: Closterium limneticum* (400x)*; LI: Geminella* sp. (400x); LII: *Phacus pleuronectes* (400x); LIII: *Euglena gracilis* (400x); LIV: *Phacus curvicauda* (400x); LV: *Phacus orbicularis* (400x) LVI: *Phacus acuminatus* (400x); LVII: *Phacus* sp. (400x) LVIII: *Calothrix* sp. (400x); LIX: *Glaucocystis* sp. (400x); LX: *Cladophora glomerata* (100x); LXI; *Nitzschia nana* (400x); LXII: *Gomphonema* sp. (400x);

DISCUSSION

The investigation into the temporary and spatial variability in microalgae community structure within Nsit Ubium River aimed to deepen our understanding of the intricate relationships between environmental variables and microalgae composition. In this study, a total of 56 algal species from six orders were identified across two distinct stations, Inyang Udo Nsinia Stream (Station 1) and Ikot Okobo Stream (Station 2). Bacillariophyta emerged as the most abundant order, consistent with studies by Smith *et al*. (2018) in similar freshwater ecosystems. The spatial distribution of these microalgae revealed variations in community structure, with Station 1 exhibiting 75% occurrence of Bacillariophyta compared to 66.67% in Station 2.

Our study align with the broader literature on microalgae community dynamics, emphasizing the influence of local environmental conditions on species composition (Jones and Grey, 2019). The significant presence of Bacillariophyta underscores their adaptability to varying ecological niches and nutrient levels (Smetacek, 2018). They are acid loving hence the reason for the dominance in that station of pH 5.3 and 5.2 respectively. Moreover, the identification of specific species such as *Pinnularia borealis, Nitzschia pusilla*, and others provides valuable insights into the biodiversity of Nsit Ubium River, corroborating studies emphasizing the importance of understanding algal diversity for ecosystem health (Hillebrand *et al.,* 2020).

The percentage occurrence of algal orders depicted in Figure 1 and Figure 2 visually represents the distinct composition patterns at the two stations. Notably, Chlorophyta and Euglenophyta exhibited higher percentages in Station 2, suggesting potential correlations with specific environmental factors unique to Ikot

Okobo Stream. This finding resonates with studies by Johnson *et al.* (2021), highlighting the sensitivity of Chlorophyta to nutrient variations. The identification of indicator species, such as Spirogyra sp., as representative of specific environmental conditions, further supports the ecological relevance of microalgae in reflecting ecosystem health (Lepelletier *et al.,* 2017).

The physicochemical parameters measured in both stations shed light on the environmental context influencing microalgae communities. The slightly acidic pH values (5.3 in Station 1 and 5.2 in Station 2) align with the preference of many microalgae species for slightly acidic to neutral conditions (Padisák *et al.,* 2018). However, the variations in nutrient concentrations, specifically the higher phosphate levels in Station 2, might explain the observed differences in microalgae composition between the two stations. This aligns with the findings of Wang *et al.* (2019), emphasizing the role of phosphorus in shaping algal communities.

While this study contributes valuable insights into the microalgae community structure in Nsit Ubium River, it is essential to acknowledge its limitations. The six-month sampling duration may not capture long-term trends, and additional seasonal variations could provide a more comprehensive understanding. Furthermore, the absence of dissolved oxygen (DO) measurements limits our ability to assess the potential impact of oxygen levels on microalgae dynamics, a consideration for future studies.

The findings of this study elucidate the complexity of microalgae communities in Nsit Ubium River and emphasize the intricate interplay between environmental variables and algal composition. The identification of indicator species and the spatial distribution patterns provide a foundation for ongoing monitoring and conservation efforts in this unique freshwater ecosystem. The study's outcomes contribute to the growing body of literature on microalgae ecology and serve as a basis for informed decision-making in the management of Nsit Ubium River and similar environments.

Conclusion

Our study into the temporary and spatial variability in microalgae community structure within Nsit Ubium River has provided valuable insights into the diverse and dynamic nature of these aquatic ecosystems. The identification of 56 algal species from six orders, with Bacillariophyta prevailing as the most abundant, highlights the rich biodiversity of Nsit Ubium River. The study's emphasis on spatial distribution, indicator species, and the correlation with physicochemical parameters contributes to our understanding of the ecological significance of microalgae in responding to environmental variations. While the study sheds light on the microalgae community dynamics, it is crucial to acknowledge its temporal limitations and the absence of dissolved oxygen measurements. Nonetheless, the findings offer a foundation for future research and conservation efforts in Nsit Ubium River and similar freshwater ecosystems.

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FISHING GEAR-RELATED INJURIES AND MORTALITIES TO BIRD POPULATION IN HADEJIA-NGURU WETLANDS, NORTHEASTERN NIGERIA

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ABSTRACT

On a continental scale, bird populations continue to face increasing threats. Threats like habitat loss and degradation, and recently climate change have been well documented. The effect of fishing gear on bird injuries and mortalities have mainly been studied in seabirds, and largely unknown in freshwater birds. We documented bird injuries and deaths caused by fishing gear in the Hadejia-Nguru wetland between 2018 and 2023. The total number of bird species found entangled was 10. Only two bird species were released successfully, with the rest dead. We also recovered 7 rings from dead birds found entangled in the fishing gear. These birds are used by researchers around the world for monitoring bird life histories such as migration and lifespan. Our results present the consequences of abandoned fishing gear yet an understudied area of research in Nigeria. Community engagement and awareness programs may enlighten the public, more especially fishermen about the harm of fishing gear to bird populations. We recommend studies to account for comprehensive data on the impacts of fishing gear on bird populations in this important wetland.

Keywords: Fishing gear, Fishermen, Bird mortalities, Waterbirds, Outreach programmes

INTRODUCTION

Human activities continue to impact biodiversity at an alarming rate. While habitat loss and degradation, deforestation, pollution, and urbanisation play a role in widespread declines in bird populations, other human impacts are not well studied. One of the human impacts is fishing gear, which leads to entanglement and subsequent death of birds (Ryan, 2018; Watkins *et al.,* 2008). This is especially true for birds living in marine environments. Studies examining the effect of fishing gear on bird population have been carried out around the world (Dau *et al.,* 2009). Studies by Favero et al. (2011) showed that several hundred to over a thousand mortality of Black-browed albatross (*Thalassarche melanophris*) was due to collisions and entanglement in fishing gear. Watkins et al. (2008) documented nearly 30 bird mortalities within 190 hours of dedicated observations on the coasts of South Africa.

Bird populations in Nigeria are facing high rates of threats and subsequent mortalities owing to increasing human activities. Although the number of bird species considered threatened is not as high as elsewhere, it is presumed that these birds are locally declining. Of the nearly 900 bird species in Nigeria, only 3% are considered threatened (Birdlife International, 2024). However, this percentage may unlikely hold in the recent years considering the high prevailing environmental problems in the country. Increasing habitat degradation, and loss because of high rates of deforestation and expansion of agricultural activities in the savannas are believed to be fast driving the declines of bird populations (Dami, Mwansat, and Manu, 2013). Bird studies and assessment related to threats in Nigeria have been based on other human influences not fishing gear. Muhammad et al. (2015) show that Typha grass invasion in the Hadejia-Nguru wetlands (HNWs) affects bird diversity. Ringim and Harry (2017) gave an account of how farming, fishing, and grazing influence bird communities in the HNWs.

This paper appears to present a novel account of the effects of fishing gear on the bird population in Hadejia-Nguru wetlands (HNWs). The importance of this preliminary account is twofold, the effect of fishing is brought to light as an understudied area of research in Nigeria. Secondly, the paper discusses the importance of sensitization and outreach programs for a win-win situation between the local communities - fishermen and bird populations. We hope that this will ignite more comprehensive studies on this line of emerging area of research.

Materials and methods

The Hadejia-Nguru wetlands

The HNWs is the first Ramsar site in Nigeria declared in 2000 (Fishpool and Evans, 2001). The wetland consists of lakes, ponds, marshes, swamps, floodplain areas, and forests. The wetland is known to support an incredible population of resident and migratory bird populations (Muhammad *et al.,* 2022). It is recognized as one of the 27 Important Bird and Biodiversity Areas in Nigeria (Fishpool and Evans, 2001). The HNWs is recently recognized as the only site in Nigeria fitting the criteria of the International Union for Conservation of Nature Freshwater Key Biodiversity Areas' framework (Nigerian Conservation Foundation, unpublished report). There are four protected areas in the HNWs, Adiani Forest Reserve, Baturia Game Reserve, Nguru Lake and Marma Channel, and Dagona Waterfowl Sanctuary. The wetland produces over 6% of Nigeria's freshwater fisheries (Eaton and Sarch, 1997). Most of the wetland inhabitants greatly engage in fishing, agriculture, livestock grazing, and other utilisations, such as fuel wood collection, wildlife collection, honey, etc. providing immense livelihood support (Ayeni, *et al.,* 2019).

We documented the numbers and bird species entangled in fishing gear during field works in the HNWs. In scenarios when conducting fieldwork on water bodies using the canoe, we removed the submerged abandoned fishing gear to see if there were birds entangled in the gears. The conservation status and trend of the birds are under the International Union of Conservation of Nature (IUCN) RedList of Threatened Species (Birdlife International, 2024b). Information and rings recovered from the bird killed an abandoned fishing gear were recovered rings were sourced from fishermen or where? Wherever possible, we removed the fishing gear from the water bodies to help prevent further bird entanglements.

Results

We documented 10 bird injuries and mortalities from an abandoned fishing gear in HNWs between March 2018- November 2023 (Table 1). The number of rings recovered from

dead birds were seven. All the bird species presented in the Figures below are non-migratory except for Garganey (*Spatula querquedula*), Osprey *Pandion haliaetus*, and Squacco heron (*Ardeola ralloides*), which are Palearctic migratory birds. The Knob-billed duck is an Intra-African migrant. Among these entangled birds, a ringed Osprey and Squacco heron were disentangled and released successfully. The Osprey was entangled at Ruwan Mosa wetlands in Arki community Malam Madori Local Government, Jigawa State. A follow up to this ringed bird turn out to be ringed by researchers at the University of Helsinki in Finland. The life history of this bird is available at *https://www.premiumtimesng.com/entertainment/naija-fashion/293830-migratory-bird-belonging-to-university-of-helsinki-trapped-released-in-nigeria.html*

Table 1: Names of entangled birds recorded in an abandoned fishing gear in Hadejia-Nguru wetlands, March 2018- November 2023

Species	Number of observations	Conservation status ad trend	Location/remark
Garganey *Spatula querquedula*	1	Least Concern, decreasing	Zemo, dead
Knob-billed duck *Sarkidiornis melanotos*	2	Least Concern, decreasing	Zemo, dead
White-faced whistling duck *Dendrocygna viduata*	1	Least Concern, increasing	Zemo, dead
Common moorhen *Gallinula chloropus*	1	Least Concern, stable	Zemo, dead
Little bittern *Ixobrychus minutus*	1	Least Concern, decreasing	Marma Channel, dead with ring equipped.
Squacco heron *Ardeola ralloides*	2	Least Concern, unknown	Tukun Zuru, dead 1 found in Baturiya, released
Black heron *Egretta ardesiaca*	1	Least Concern, stable	Tukun Zuru, dead
Spur-winged lapwing *Vanellus spinosus*	1	Least Concern, increasing	Zemo, dead
Osprey *Pandion haliaetus*	1	Least Concern, increasing	Arki, equipped with ring and released.
Northern white-faced owl *Ptilopsis leucotis*	1	Least Concern, stable	Zemo, released.

Plate 2: a) Entangled Black heron *Egretta ardesiaca*, b) Squacco heron *Ardeola ralloides.* These birds recorded in at Tukun Zuru wetland

Figure 3: a) Knob-billed duck (*Sarkidiornis melanotos*), b) Garganey (*Spatula querquedula*). These birds were observed entangled in an abandoned fishing gear in Zemo wetland.

Figure 4: Squacco heron entangled at fishing gear in Baturiya, White-faced whistling duck (*Dendrocygna viduata*) entangled at an abandoned fishing gear in Zemo wetlands

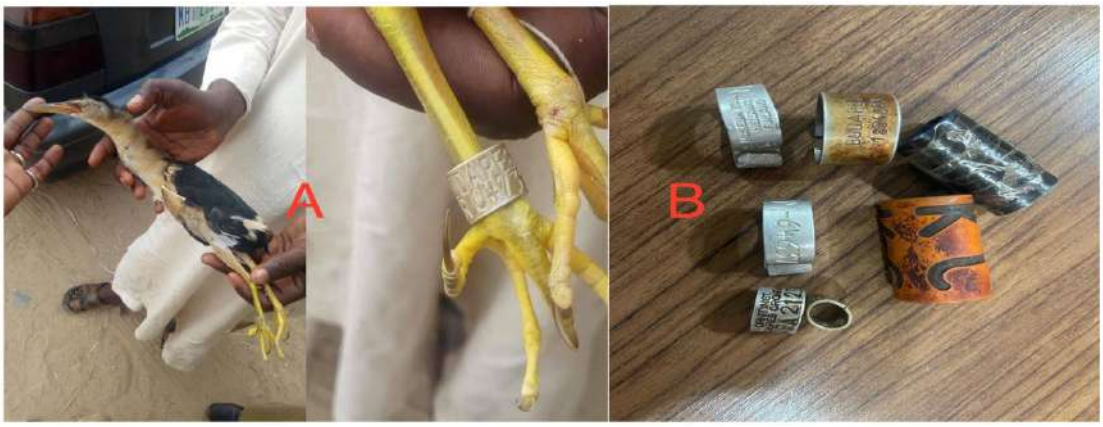

Figure 5: a) An entangled and dead Little bitten (*Ixobrychus minutus*) in nets recovered from a fisherman at Marma Channel, b) Recovered rings from entangled (dead) waterbirds in the HNWs.

Figure 6: Northern white-faced owl (*Ptilopsis leucotis*) Common moorhen (*Gallinula chloropus*). These birds were observed entangled in an abandoned fishing gear in Zemo wetland.

Figure 7: Knob-billed duck (*Sarkidiornis melanotos*) and Spur-winged lapwing (*Vanellus spinosus*), observed in an abandoned fishing gear at Zemo wetland.

Figure 8: A) Mal Yunusa, the fisherman that found the entangled Osprey (*Pandion haliaetus*) in his fishing gear, b) Ibrahim Lawan Muhammad (Director Nature Conservation Department,

Ministry of Environment, Jigawa State) who rescued and released the Osprey at Baturiya wetlands on November, 2018

DISCUSSION

Our study shows that abandoned fishing gear in HNWs poses a threat to bird populations. We found that bird injuries and deaths were associated with abandoned fishing gear. Studies from around the world have shown fishing gear to negatively impact avian populations, particularly in seabirds (Favero et al., 2011; Ryan, 2018; Watkins et al., 2008). Our study on the threat of fishing gear in wetlands further sheds light on this area of research. Although all the bird species recorded are not recognized as birds of conservation concern, the fishing gear has the potential to cause mortalities in bird species with significant values. All the birds documented are waterbirds and water-related birds, highlighting increasing dangers facing these birds apart from wetlands degradation and loss (Kingsford and Thomas, 2004).

The findings suggest non-migratory and migratory bird populations are at risk of becoming entangled. While the Osprey forage on fish species, making them highly vulnerable to becoming entangled. These birds scavenge on fishing gear in an attempt to get easy food, which also increases the chance of injuries or death in fishing gear. This is also true for the Squacco heron, which primarily feeds on fish and other aquatic invertebrates. Although the ducks do not feed on fish nor scavenge on fishing gear, they are vulnerable to kills in fishing gear when left in the water body where the birds utilized for foraging, diving, and roosting.

The Zemo wetlands appear to pose the greatest threat to bird population injuries and deaths. This is because of the number of birds recorded in the wetland. The probable reason could be that the wetlands are surrounded by Dala communities, where high-level fishing activities (festivals) for days are carried out on an annual basis. After this festivity, the fishing gears are abandoned in the wetland. Tukun Zuru wetland in Baturia was another site where we observed injured and dead birds, including Squacco and Black herons. The fishermen have also claimed to release birds found entangled in fishing gear. The number of bird mortalities resulting from the fishing gear is currently unknown because of poor documentation and research.

Often, the injuries and mortalities are called to attention when an entangled bird is found with a ringed, or equipped with loggers or transmitters. This is evident from the recovered rings presented in this study. Perhaps, the dangers of fishing gear have spread across other wetlands in Nigeria, but could not be accounted for owing to the lack of research in this area. Researchers use birds equipped with rings or transmitters to learn important aspects of the life histories of birds, namely migratory routes, staging sites, lifespan, and energy utilisations (Guilford et al., 2011). When these birds become entangled and subsequently perish in fishing gears, the research studies become imperil due to insufficient data to support the hypothesis being tested. This also jeopardies the ongoing collaborative conservation efforts to protect migratory birds at the continental scale.

Community engagement and awareness programs may enlighten the public about the harm of fishing gear to bird populations.

Specifically, these programs could focus on solutions related to the proper disposal of used fishing gear after usual or annual fishing festivals. The fishermen may also be sensitized about alternative fishing gear that poses less risk of injuries and mortalities to bird populations. Collaboration among different wetland stakeholder groups would help develop and implement sustainable fishing practices for a win-win situation between human livelihoods and bird conservation in the HNWs. We recommend studies to account for comprehensive data on the impacts of fishing gear on bird populations in this important wetland.

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ASSESSMENT OF LAND MANAGEMENT PRACTICE AND SOIL CONSERVATION AMONG MAIZE-BASED FOOD CROP FARMERS IN SOUTHWEST, NIGERIA

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ABSTRACT

The study examined the determinants of various land management practices and conservation methods on maize farmers' output in Southwest, Nigeria. Multistage sampling technique was used to select 480 maize farmers in the study area. Interview schedule was used to elicit needed information such as age, land conservative/management practice and production characteristics of maize farmer in the study area. Data were analyzed using descriptive statistic and stochastic production function (SPF). The result revealed that 70.8%, 70.5% and 89.2% were male, married and literate respectively with mean household size estimated at 4 persons. About 33.0%, 9.2% and 1.0% adopted planting cover crop, mulching and fertilizer application respectively as means of land management practices while 28.3% and 48.3% of the farmers adopted crop rotation and mixed cropping as land conservation practices. SPF showed that farm size ($p<0.01$), labour ($p<0.01$), land management practice ($p<0.01$) and land conservation practice ($p<0.01$) have a significant influence on maize production in the study area. The study concluded that land management practice and land conservation practice were determinant factor in maize production. The study recommended that government should encourage research that will be of farmer specific for awareness to be created on how to improve the quality of farm management practices.

keywords: Land Management, Stochastic Production Function, Maize Cultivation, Soil Conservation

INTRODUCTION

Land is the major resource for the livelihood of the poor. In Nigeria, a typical villager recognizes land in its entirety. Oluwatayo et al. (2008) reported that land to the farmer is like home and work place and shares it with the entire biotic complex. As important as land is to farmers' livelihood, Arimi (2014) observed that subsistence farmers are with a lot integrating constraints on land management practices. These constraints are under three headings; economics obstacles such as capital need and financial incentives; social conditions which include land tenure, availability of infrastructures and educational level of farmers; and ecological consideration such as limited knowledge of inputs and sustainability of some systems. Land use, in many African nations, has been characterized by a significant amount of land degradation. Moreover, these two processes are clearly related. Many poor African pastoralists and farming households respond to declining land productivity by abandoning existing degraded pasture and cropland, and moving to new land for grazing and crop cultivation. Due to the fact that the pattern of land use will often result into depletion of soil nutrients, appropriate management practices have to be adopted. Oluwatayo *et al*. (2008) noted the need for appropriate soil management in tropical soil to sustain increased crop yields as cultivation continues on an annual basis. This was traced to the fact that clay in most tropical soil, referred to as low activity clay (LAC) does not expand and contract readily with moisture changes and the soil becomes

susceptible to soil compaction. Also, LAC soils have a low cation exchange capacity, which means that nutrients are not held by the soil, but quickly leached below the crop roots. This is due to high temperature; which makes organic matters in tropical soil to be susceptible to rapid mineralization.

Furthermore, in an imperfect market setting, the nature of poverty is also important in determining its impact on natural resources management and degradation. Households that are not poor by welfare criteria such as minimum levels consumption may still face "investment poverty" that prevents them from making profitable investments in resource conservation and improvement.

Problem statement

The study was informed by the declining food crop production in Nigeria. Food crop production in Nigeria no longer keeps with population growth. Thus, creating a wide gap between the demand and supply of food (Abdulrahman, 2013). This is evidence in the observed food crop deficit and the upward trend in the price of foodstuff in the market over the years (Food and Agriculture Organisation, 2006). The growth of Nigeria economy with reference to agriculture has been import driven rather than production driven. Consequently, there is a growing advocacy for improving Nigeria agricultural production so as to achieve sustainable food security. According to Abdulrahman (2013), a lot of effort has been directed at finding appropriate institutions for organizing millions of small-scale farmers towards achieving food security (through increased food crops production) and agricultural productivity. Food production could be affected by the farmer's age, access to credit, gender, farm size, educational level and farming experience. It is on record that 50% of world's population is dependent on subsistence agriculture. The effect of this is high, underfeeding and malnutrition throughout the nation. Nigeria as a nation only depends on rural inhabitants who constitute over 15% of the total population for the production of foods (FAO, 2006). These farmers are poor subsistence farmers and they spend little on food production, which lead to low productivity.

Moreover, Nigeria is witnessing an upward trend in price of foodstuff, which should not be attributed to inflationary tendencies alone. The price increase is mainly due to decrease in production coupled with rise in demand as a result of increase in population and purchasing power. For example, cassava products were reported to be declining by less than 10% for reasons connected with losses from livestock and declining soil fertility which is a result of the effect of land productivity (Amaza and Olayemi, 2000). Hence, there is every need to increase food crop production due to increase in human population so as not to cause hunger and starvation among the teeming population.

This study was therefore conceived to determine the technical efficiency of maize production in Ogun State, Nigeria. Hence, the specific objectives are to describe the socioeconomic characteristic of maize farmers, examine the type of land management and conservation practices adopted by maize farmers and determine the effect of land management practices on Maize production in the study area.

METHODOLOGY

Study area

The study was carried out in Ogun State, South Western Nigeria. The State lies between longitudes 2°2` and 3°55` and latitudes 7°01` and 7°18`. It has a tropical climate with rainforest vegetation on its southern part and a derived savannah on its northern end. It has an estimated land area of 16,409.26 square kilometers. The estimated human population is 3751140

(2006 population census) and it is characterized commercially by a dual economic focus, the bourgeoning industrial sector and a dominant agricultural sector. The vegetation is largely rainforest and savannah and this makes it possible to cultivate many crops ranging from tree crops to arable crops and food crops. The farmers in the State cultivate crops, such as, maize, cowpea, cassava, melons, cashew, cocoa, oil palm, and vegetables.

Sampling procedure and Data collection

The study populations were mainly rural farming households who engaged in maize crop production in the study area.

Multistage sampling method was used to select 240 farming households from 20 communities in two Agricultural Development Programme (ADP) zones of Ogun State. First stage involved the selection of two Zones which are Abeokuta and Ilaro randomly. Second stage involved simple random selection of three (3) blocks from Abeokuta Zone and two (2) blocks from Ilaro ADP zone. Stage three involved random selection of four (4) cells from each of the 5 blocks making 20 cells. While the last stage involved random selection of twelve (12) farming households from each of the 20 cells making 240 farming households. Primary data were collected using structured interview guide. Data were analyzed using frequency count, percentage, mean and Stochastic Production Function

RESULTS AND DISCUSSION

Socioeconomic characteristics of respondents

The socioeconomic distributions of the respondents were presented in Table 1. Distribution of age of the food crop farmers in the study area as shown in Table 1 reveals that majority (94.17 percent) of food crop farmers were aged below 61 years with the mean age of 43 years. The result was in conformity with Adebayo (2014) who pointed out that individuals were more active under the age of 50 years. This implies that most of the respondents are in their economically active age and are expected to be energetic and productive. Also, many (72.5 percent) of the food crop farmers were married with mean household size of 4 persons. Also, based on religion distribution of the respondents, majority (60.0 percent) were Christians. Distribution of food crop farmers by educational status revealed that many (50.8 percent) had secondary school education as against 10.8 percent without formal education. The mean farming experience and farm size were estimated at 9.6 years and 4.2 hectares respectively. This is contrary to Dipeolu et al. (2009) where majority of food crop farmers had no formal education while Arimi (2014) reported that majority of Nigeria's farmers are still subsistence in nature. Also, majority (72.5 percent) of food crop farmers had contact with extension agents once a year. This finding aligned with Fabusoro *et al.* (2008) that shortage of extension personnel hindered the delivery of good agricultural extension services.

Table 1: Distribution of the respondents according to the socioeconomic characteristics in the study area

Socioeconomics characteristics	Frequency	Percentage	Mean
Sex			
Male	170	70.83	
Female	70	29.17	
Age			
Less than 30	52	21.67	
31-40	48	20.00	
41-50	88	36.67	43
51-60	38	15.83	
61 and above	14	5.83	
Marital status			
Married	174	72.50	
Single	52	21.67	
Divorced	10	4.17	
Widowed/widow	2	0.83	
Separated	2	0.83	
Religion			
Christianity	144	60.00	
Islam	88	36.67	
Traditional	8	3.33	
Level of education			
Non-formal	26	10.83	
Primary	40	16.67	
Secondary	122	50.83	
Tertiary	52	21.67	
Household size			
1-2	68	28.33	
3-6	142	9.17	4
7-10	28	11.67	
10 and above	2	0.83	
Farm size			
1-5 hectares	180	75.00	4.19
6-10 hectares	16	6.67	
11-15 hectares	26	10.83	
16 and above	18	7.50	
Farming experience			
1-5 years	66	27.50	
6-10 years	94	39.17	9.6
11years and above	80	33.33	
Contact with extension agent			
None	4	1.67	
Once	174	72.50	
More than once	62	25.3	
Total	**240**	**100**	

Distribution of the respondents based on the various land management practice adopted in the study area

Table 2 revealed the various land management practices adopted by maize farmers in the study area. It was revealed that 2.50% of the respondents did not engage in any form of land management practices, 3.34% of the respondents engaged in Terracing, 1.67% of the respondents engaged in contour bonds, 1.67% of the respondents engaged in Ridge across slope, 5.83% of the respondents engaged in Crop rotation, 35.0% of the respondents engaged in Multiple cropping, 32.5% of the respondents engaged in Cover Cropping, 9.17% engaged in Mulching, none of the respondents was engaged in Agro-forestry, 2.50% of the respondents engaged in bush fallowing, 5.0% of the respondents engaged in compost, while 0.82% of the respondents engaged in Fertilizer Application. This implies that Majority of the respondents are engaged in various land management practices.

Table 2: Distribution of the respondents based on the various land management practice adopted in the study area

Land Management Practice	Frequency	Percentage
None	6	2.50
Terracing	8	3.34
Contour Bonds	4	1.67
Ridge Across Slope	4	1.67
Crop Rotation	14	5.83
Multiple Cropping	84	35.00
Cover Cropping	78	32.50
Mulching	22	9.17
Agro-Forestry	0	0.00
Bush Fallowing	6	2.50
Compost	12	5.00
Fertilizer Application	2	0.82
Total	**240**	**100**

Land conversation practices adopted by the respondents

Land conservation practice adopted by maize farmers in the study area was revealed in Table 3 that 28.33% of the respondents engaged in crop rotation, 13.33% of the respondents engaged in Bush fallowing, 48.33% of the respondents engaged in Mixed cropping, 8.33% of the respondents engaged in Planting cover crop while 1.67% of the respondents engaged in Mulching. This implies that majority of the respondents were engaged in diverse land conservation practices in the study area.

Table 3: Distribution of respondents according to land conversation practices adopted in the study area

Land conservation methods	Frequency	Percentage
Crop Rotation	68	28.33
Bush Fallowing	32	13.33
Mixed Cropping	116	48.34
Planting Cover Crop	20	8.33
Mulching	4	1.67
Total	**240**	**100**

Maximum Likelihood Estimates of the Stochastic Production Function of Maize farmers

Table 4 presents the maximum likelihood estimates (MLE) of the production function of maize farmers in Ogun State. The variance parameter for sigma-square for maize farmers was estimated at 0.741. The sigma-square attests to the goodness of fit and correctness of the distributional form of the model while the gamma value (0.641) which was significant at 5% revealed the systematic influences that were unexplained by the production function and the dominant sources of random error. This implies that about 64.1% of the variance in output of maize farmers in Ogun State is due to the differences in their technical inefficiencies or technical efficiencies.

The result showed that hired labour and farm size in hectares had positive significant influence on maize production at 1 percent. Furthermore, the finding showed that other variables such as fertilizer, agrochemical and cost of planting materials/input didn't exert any significant influence on maize production in the study area.

The contribution of farmers' personal characteristics such as Age, Years of education, Farming experience, Household size and Sex, land management practice, land conservative practice to farm inefficiency were also examined. However, all the variables examined in the inefficiency model are not significant except land management practices and land conservative practice that had negative influence on farmers' inefficiency model. This implies that land management practices and conservations practices by farmers in are predominant factors in maize production in the study area.

Table 4: Stochastic Frontier Production Function Model result of Maize farmers' production

Variables	Coefficient	Standard error	t-value
Constant	0.6231***	0.2115	2.9460
Farm size	0.4510***	0.1521	2.96515
Labour (Man days)	0.7211***	0.2007	3.5929
Fertilizer (Kg)	0.2981	0.3092	0.9641
Agrochemicals (Kg)	1.0134	0.7022	1.4431
Planting material/input (₦)	0.0207	0.0332	0.6234
Inefficiency Model			
Constant	2.1311**	1.0763	1.9800
Sex	0.5671	0.5231	1.0841
Age	0.0033	0.1128	0.0292

Education	-0.2091	0.3121	-0.6699
Farm Experience	-0.7711	0.9899	-0.7789
Household size	-0.2219	0.3441	-0.6448
Land Management Practice	-0.1952***	0.0522	-3.7394
Land Conservative Practice	-0.6493***	0.2316	-2.8035
Diagnostic Statistics			
Stigma-square ($\boldsymbol{\delta}^2$)	0.741	1.586	0.467
Gamma ($\boldsymbol{\gamma}$)	0.641**	0.311	2.061
Log Likelihood	-116.21		
Chi Square	32.21***		

CONCLUSION AND RECOMMENDATION

The study concluded that majority of the respondents were still in their economic stage, married and expected to be productive. The result of SPF revealed that hired labour and farm size in hectares exert a positive influence on maize production in the study area.

The study recommends that researchers should be result oriented, specified their researches on specific food commodity and create awareness on how to improve the quality of farm management practices currently in practice. There is need for the government to add to the present subsidy style (credit facilities support) through subsidized planting materials, inorganic fertilizers and agro-chemicals as well as provision of soft loan to farmers who were unable to benefit directly from the credit subsidies to remain in agriculture

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ENHANCING HOUSEHOLD DIETARY DIVERSITY THROUGH THE ADOPTION OF CLIMATE-SMART AGRICULTURAL PRACTICES: EVIDENCE FROM NIGERIA

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ABSTRACT

The study investigated the effects of CSA practice on the food security status of rural farming households in Nigeria. A multi-stage sampling technique was employed in selecting 480 rural farming households across three selected states from Southwest, Nigeria. Data were analyzed using descriptive and inferential statistics. Obtained results showed that 59.79% of the respondents were food insecure while severe and depth of food insecure among the farming households were 0.0711 and 0.1913 respectively. The result of the household dietary diversity score revealed the diverse consumption-ability of the respondents and the contributions of CSA practice in their farming system. This implies that households engaged in climate-smart farming are more likely to achieve higher levels of food consumption score, dietary diversity, and food security. The probit regression revealed that the food security status among rural farming households was significantly influenced by household heads' gender, farm size, and contact with extension agents as well as adopted CSA practices such as crop diversification, agroforestry, and use of Fadama land for agricultural activities. This research concludes that CSA lowered the probability of food insecurity among rural farming households in Nigeria. Accordingly, the study suggests that the government and the key players should encourage the use of CSA practices in order to ensure agricultural sustainability and food security in agrarian communities by reducing the impact of climate change.

Key words: Climate variability; Climate-Smart Agriculture; Crop diversification; Food security; Regression; Sustainability

INTRODUCTION

Food provision for households is a necessity, with approximately 820 million individuals globally being faced with the challenge of hunger, while over two-thirds of the world's population lacking essential nutrients, thus influencing their diet, well-being and life expectancy (FAO, 2019). Climate change is one of the environmental problems facing mankind. The implication of climate change cuts across various sectors, ranging from health to agriculture. Climate change has significantly affected global agriculture in the 21st century (Akanbi *et al*., 2021). The effects of climate change on agricultural production and food security are expected to intensify over time and vary across countries and regions (FAO, 2019). Despite its high contribution to the overall economy, this sector has been seriously facing challenges of many factors of which climate-related disasters like drought and floods are the major ones. Climate variability and change adversely affect agricultural sector and the situation is expected to worsen in the future (Brosch, 2021). There is a growing concern that climate change will seriously affect the ability to meet the food demands of about 10 billion world population come 2050, which is a significant reason why experts are promoting climate-smart agriculture (Akano *et al.*, 2022). Climate-smart agriculture (CSA) integrates socioeconomic and

ecological components that ensure current food production activities do not affect the ability to produce food in the future. As it stands, conventional agricultural practices, which involve growing readily available low-yielding varieties with excessive nitrogen fertilizer application, are no longer sustainable due to adding to the release of greenhouse gases (GHGs) (FAO, 2019).

The adoption of CSA among farmers in developing countries especially in Nigeria is still low despite the numerous efforts tailored towards the sensitization of farmers about its importance in mitigating against climate change (FAO, 2019). Akanbi *et al.* (2021) revealed that there are several factors contributing to low level of adoption of CSA in Sub-Saharan Africa (SSA) ranging from technical know-how, poor awareness, cost, culture, and traditional beliefs, and poor infrastructures, financing, unsustainable government policy, and other socioeconomic constraints such as education level and years of farming experience. Amare *et al*. (2018), pinpointed that there is dire need of farmers to prepare towards climate change impacts by embracing adaptation and risk mitigation measures such as climate-smart agriculture so as to achieve food security in households level and globally. This article seeks to contribute to the body of knowledge on how to enhance food security in rural farming households through climate smart agricultural practices. The study aims to identify various CSA practices and to determine the effect of CSA practices on food security status using Nigeria as the case study.

MATERIALS AND METHODS

Study Area

This study was carried out in the rural Southwest, Nigeria which consists of six states, namely: Ekiti, Osun, Ogun, Oyo, Ondo, and Lagos. The area is bounded in the East by Delta State, the Republic of Benin in the West, Kwara and Kogi State in the North and by the Atlantic Ocean in the south. The main occupation in the geopolitical zone is farming, with maize, cassava, yam, oil palm, cocoa and timber being produced commercially. Most rural families in the zone survive on subsistence farming, with supplementary income from other employment, such as trading, hunting, food gathering and handcraft. This resulted in the rural households dropping into a more severely poor category, resulting in the majority having to depend on savings and help from relatives.

2.2 Sampling techniques and data analysis

Primary data were used for this study and were collected through the use of a structured questionnaire. The sampling population consisted of rural farming households mainly engaged in subsistence farming. A multi-stage sampling procedure was used to select 480 rural farming households across six states that made up the Southwestern, Nigeria. First stage involved random selection of 50% of the States (Oyo, Ekiti and Ogun) that made up of Southwestern geopolitical zone. The second stage involved selecting two Agricultural Development Programme (ADP) Zones from each state, making six zones. The third stage involved randomly selecting two blocks from each of the six ADP zones, making 12 blocks. Fourth stage involved randomly selecting four cells from each of the 12 blocks, making 48 cells. Last stage, involved randomly selecting 10 households from each of the 48 cells, which totaled 480 rural farming households. The data collected were analyzed using descriptive statistics (means and frequencies). Logit regression model was used to determine the effect of CSA practices on food security status of the respondents, while the Foster–Greer–Thorbecke (FGT) Index was used to classify the farming households into food secure and insecure.

RESULTS AND DISCUSSION

Descriptive statistics

Table 1 presents the socioeconomic characteristics of the respondents, with more than two-thirds of the households being male-headed (81.0%), with their mean age estimate at 47 years, thus revealing that they are expected to be productive with the available resources. This was in line with Akano *et al*., (2021), who pinpointed that the mean age of respondents in rural farming households of Nigeria was between the ages of 45 - 50 years. About 76.00% of the respondents were married, 78.00% had farming as their main source of livelihood activities with mean household size and farm size of 5 persons and 3.77 hectares respectively. Majority (72.00 percent) of the rural farming households earned less than $250.00 while about two-thirds (81.0 percent) of them had contact with extension agents. Extension agent is very important in information dissemination and adoption of new technology (Akter and Ahmed, 2021). The result of the climate smart agricultural practices (CSAP) used by the respondents revealed that crop diversification is the form of CSAP mostly used in the study area. About 3.13% of the respondents are low users while 61.25% and 15.63% of the respondents are medium and high users respectively (Fig. 2). The result was in line with Amare *et al*., (2018) who positioned that CSAP in rural areas are being silent and the importance are not well pronounced which could be the reason for its moderate usage in the study area

Table 1: Summary of the socioeconomic characteristics of the respondents (n = 480) $1 = ₦720

Variable	Mean	SD*
Gender of respondent (1 = male, female = 0)	0.81	0.193
Age group (1 = adult; 0 = youth)	47.1	0.201
Education level of respondent (1 = formal; 0 = Non formal)	0.62	0.117
Household size (number)	5.31	0.410
Marital Status (1 = Married; 0 = Otherwise)	0.76	0.291
Farm size (hectares)	3.77	1.321
Farming experience (years)	8.23	1.092
Contact with extension agent (1 = yes)	0.81	0.018
Main source of income: (1 = Farming, 0 = Others)	0.78	0.512
Income from farming: <250 USD	0.72	0.221
251 - 500 USD	0.20	0.012
> 500 USD	0.08	0.162

***SD: Standard Deviation**

Table 2: Climate Smart Agricultural Practices (CSAP) and Degree of Usage

Climate Smart Agricultural Practices	WMS	SD
Crop diversification	4.723	1.004
Crop rotation	4.281	0.961
Mulching	2.104	0.452
Agroforestry	1.982	0.142
Use of Organic manure	3.441	0.811
Use of Fadama land	2.981	0.051
Planting crops with early maturity	3.831	1.031
Planting drought-tolerant crop varieties	4.016	1.441
Planting cover crop	1.052	1.113
Intercropping	4.101	0.742
Irrigation	1.961	0.022

WMS = Weighted Mean Score SD = Standard Deviation

Table 3: Various climate-smart agricultural practices (CSAP)

CSAP	WMS	SD
Crop diversification	4.723	1.004
Crop rotation	4.281	0.961
Mulching	2.104	0.452
Agroforestry	1.982	0.142
Uses of organic manure	3.441	0.811
Uses of Fadama land	2.981	0.051

Planting early-maturity crops	3.831	1.031
Planting drought-tolerant crop	4.016	1.441
Cover crop planting	1.052	1.113
Intercropping	4.101	0.742
Irrigation	1.961	0.022

WMS = Weighted Mean Score
SD = Standard Deviation

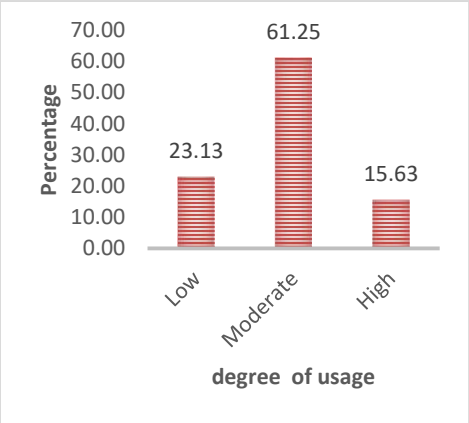

Fig. 1. Degree of usage of CSAP by the respondents

4.1 Household food security

4.1.1. Household Dietary Diversity

Table 3 revealed the categorization of sampled rural farming households according to their HDDS threshold (μ = 5.12). Following Abegunde *et al.,* (2022) and Omotayo *et al.,* (2022) in regards to the significance of dietary variety scores in determining food security. Households with dietary diversity scores of 3 were classified as having low dietary diversity; those with scores of 4-6 were defined as having medium dietary diversity; and those with scores of 7 were classified as having high dietary diversity. Furthermore, Table 4 itemized household groups based on food security categories. Following FAO (2022) guideline using the mean HDDs threshold, HDDS was used to group rural farming households into food secure and insecure categories. Households with HDDS above the threshold (μ = 5.12, SD = 1.97) were considered food secure, whereas those with HDDS below the threshold were classified as food insecure. The result revealed that about 60.00% of rural farming households were food insecure while about 40.00% of them were food secure.

Table 3. Categorization of rural farming households based on dietary diversity

Categories of Households	Pooled		Male-headed		Female-headed	
	Frequency	%	Frequency	%	Frequency	%
Low Dietary Diversity	120	25.00	105	26.99	33	36.36
Medium Dietary	292	60.83	235	60.41	47	51.65
High Dietary	68	14.17	49	12.60	11	12.09
Total	480	100.00	389	100.00	91	100.0
Mean Score of Dietary Diversity	5.12	SD = 1.97				

Table 4. Food security status of the rural farming households (μ = 5.12)

Food security status	Frequency	%
Food Secure	193	40.21
Food Insecure	287	59.79
Total	480	100.00

4.2.3 Household food insecurity indices

Following Omotayo *et al.* (2021), P_0 (food insecurity incidence (headcount)), P_1 (depth food insecurity) and P_2 (severity food insecurity) were food insecurity parameters used. Food insecurity head count showcase the proportion of sampled households below

the food security line (Omotayo, 2016; Omotayo *et al.,* 2022). The results in Table 7 showed that the food insecurity headcount ratio within the households was 0.4205, indicating 42.05% of the farming households were food insecure (unable to achieve the daily required food security level), while 57.95% were food secure. The food insecurity gap was estimated to assess the extent to which food-insecure households fall below the acceptable food security threshold. This gap depicts the many forms of food insecurity faced by agricultural households in the research region.

Furthermore, P_1 (depth food insecure) of the sampled farming households was 0.1913. This indicates that, theoretically, food insecurity may indeed be abolished if resources were deployed to fulfill 19.13% of the calorie requirements of all food-insecure households. The agricultural households' P2 (severe food insecurity) value was 0.0711, signifying that the respondents' food insecurity severity was 7.11%. This resulted in an estimated core food insecure home requiring around 7.11% of the food insecurity line to the households' food budget in order to move out of their severe food insecurity state. In accordance with the findings of the study, food insecurity exists among rural households in the study area. This is in accordance with the findings of Babalola (2018) and Omotayo *et al.* (2022), who found that the vast majority of rural farming households in Nigeria are food insecure.

Table 5. Food insecurity indices among the rural farming households

Food Insecurity Status	Value
Incidence of Food Insecurity (P_0)	0.4205
Depth food insecure (P_1)	0.1913
Severe food insecure (P_2)	0.0711

4.1.3 Households food consumption

Table 6 revealed the distribution of rural farming households based on food consumption score. Majority (73.95%) of the farming households had acceptable food consumption scores while 20.42% and 5.63% of them had borderline and inadequate food consumption. This showcases the diverse consumption-ability of the respondents across the study area.

Table 6. Distribution of respondents based on households' food consumption score

Categorization of households based on food consumption score	Frequency	%
0 – 17 (Poor)	27	5.63
17.1–30 (Borderline)	98	20.42
Above30 (Acceptable)	355	73.95
Total	480	100.00

4.4 Maximum likelihood estimate of Logit regression of the effect of CSA practices on food security status

The result of the logit regression analysis showing the effects of selected socio-economic characteristics of the respondents and CSA practices on the food security status of the respondents (as shown in Table 7). The statistically significant variables affecting the food security status of the farming households were gender of household head ($p<0.1$), farm size ($p<0.01$), contact with extension agent ($p<0.05$), main occupation ($p<0.05$) and CSA practices ($p<0.01$). The gender of household's head was positive (0.1045) and significant ($p<0.1$), implying that a male-headed household had a higher probability of being food secure compared to their female counterparts, and might be due to more males have higher income generating

activities. The result was buttressed by Rahman *et al*. (2021) who reported that there are more food secure male-headed households than female-headed in Nigeria. In addition, the coefficient of farm size was positive (1.3011) and significant ($p<0.01$). This shows that the larger the farm size of a household the more the likelihood of being food secure. The coefficient of the education status of the household's head was positive (0.1167) and significant ($p<0.05$), which implies that educational level had a higher probability of leading to a food secure status. Education is expected to increase the capacity of farmers to obtain, process and utilize information relevant to the adoption and management of agricultural practices (Onyeneke *et al*., 2018). The coefficient of access to extension service and training was positive (1.0413) and significant ($p<0.05$), implying that an increase in access to extension service increased the likelihood of being food secure.

Furthermore, coefficient of CSA practices was positive (2.0017) and significant ($p<0.05$), indicating that the more CSA practice, the higher probability of being food secure in the study area. The results imply that CSA adaptation would brighten the chances of farming households in the study area to be food secure. This result agrees with McClement (2019) on study of CSA practices and food security in smallholder production systems in SSA, which reveal that farmers who adopted CSA practices were at a better level of being food secure than non-adopters. The Adjusted R^2 of 0.6275 implies that the explanatory variables explain about 62.75 % of the variations in the logistics regression model of the effect of CSA practices on food security.

Variables	Coefficient	Robust Standard Error	Z	Marginal effect
Constant	-0.1218***	0.1173	-2.4145	-0.0152
Gender	0.1045*	0.0891	1.8871	0.0229
Formal Education	0.1167**	0.0316	1.9409	0.0231
Household size	-0.0021	0.2184	-0.9618	-0.1209
Farm size	1.3011***	0.7101	2.3314	0.0321
Farming experience	-1.0019	0.5331	-0.9928	-0.0318
Farm income	0.0031	0.0346	1.0201	0.0313
Contact with Extension agent	1.0413**	0.1942	1.9903	0.0122
Main occupation	0.1043	0.2813	1.1193	0.0218
CSA Practice	2.0017***	0.5012	2.6711	0.1033
Likelihood =	-157.021			
Pseudo R^2	0.6275			
Chi Square	35.42***			
Number of observations	480			

Note: ***, **, and * represent 1%, 5%, and 10% significance level, respectively

CONCLUSION AND RECOMMENDATIONS

This article focused on various CSA practices in the study area, level of usage and then examined the effects of the level of usage of CSA on household food security. The study revealed that use of climate smart agricultural practices improved the food security status of farming households, with 57.5% of them being food secured and 42.5% being food insecure. Furthermore, crop diversification, crop rotation, planting of drought/heat tolerant crops, intercropping and using organic manure were among the highly accepted CSA practices by the sampled farming households in the study area. The result revealed that mainstreaming CSA into food crop production would impact the livelihood and food security status of small-scale farming households in the study area.

Based on the findings, the study recommends that government and all stakeholders should promote and encourage the adoption of CSAP that will ensure agricultural sustainability in agrarian communities through mitigating the effect of climate change. Also, farmers should be encouraged to diversify their source of livelihood, this will help to adopt the various forms of CSAP without lacking income for the sustenance of their households.

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INTEGRATING INDIGENOUS KNOWLEDGE INTO ECOSYSTEM RESTORATION: A PATHWAY TO SUSTAINABLE FUTURE

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ABSTRACT

In light of the declining biodiversity and increasing environmental degradation, ecosystem restoration has gained significant importance. Conventional methods, however, frequently fail to recognize the priceless insights inherent in Indigenous knowledge systems, which have preserved human-environment interactions for millennia. Restoration efforts can improve ecological resilience, support cultural variety, and create inclusive, equitable pathways toward a sustainable future by integrating Indigenous knowledge. In order to achieve sustainability, this research investigated how Indigenous knowledge may be included into ecosystem restoration techniques. We highlighted the significance of respectful collaboration, knowledge sharing, adaptive management, place-based approaches, policy, institutional support, and capacity building in realizing the full potential of Indigenous knowledge in restoration initiatives, drawing on case studies and interdisciplinary literature.

Keywords: Indigenous Knowledge, Ecosystem Restoration, Sustainable Partnership.

INTRODUCTION

Research indicates that lands managed by Indigenous populations release at least 73% less carbon than lands managed by other groups, and that 80% of the world's remaining forest biodiversity is found within the territories of these peoples (IUCN, 2019). It is impossible to overestimate the significance of ecosystem restoration in resolving environmental issues since it is essential to reducing the negative effects of human activity on the environment and promoting a sustainable interaction between society and the environment. Numerous essential services, such as clean water and air, soil formation, nutrient cycling, climate regulation, and habitat provision for biodiversity, are provided by ecosystems. However, the depletion of natural resources, pollution, overuse of natural resources, habitat deterioration, and climate change are some of the issues that are putting these services in jeopardy (Aggarwal and Elbow, 2016).

Ecosystem restoration becomes apparent in this setting as a vital approach to bring an end to environmental deterioration, preserving biodiversity, and advancing sustainable development. The goals of restoration initiatives are to improve the ecological roles of damaged ecosystems, repair their ability to support human and natural needs, and restore their ability to deliver ecosystem services. Restoration aids in food security, water resource management, biodiversity conservation, habitat restoration, and ecosystem resilience building. It also helps mitigate the effects of climate change.

In an effort to draw attention to the magnitude of the worldwide issue of restoring damaged landscapes, the UN General Assembly proclaimed 2021–2030 the "UN Decade on Ecosystem Restoration" (Ambe and Obeten, 2020). This entails working with a variety of stakeholders and utilizing complementary knowledge systems (Martin *et al.*, 2010). In other words, restoration happens throughout a range of success. (Wortley *et al.*, 2013).

Indigenous land stewardship concepts are almost usually predicated on a close understanding of local ecosystems, as ecological knowledge is transmitted through "oral traditions" (Tengö *et al*., 2014). When developed and implemented to remove obstacles to Indigenous self-determination and land access, collaborative techniques have the potential to maximize advantages for both parties (Austin et al. 2019). Frequently, western practitioners have underestimated these differences, ignored them, or even written them off as unimportant to restoration results (Zedler and Stevens, 2018).

Degradation of ecosystems puts human well-being and livelihoods at serious risk in addition to endangering the robustness and health of natural systems. Ecosystems become less resilient, stable, and productive when there is a loss of biodiversity, which leaves them more vulnerable to outside influences like disease outbreaks, invading species, and extreme weather (Blois et al., 2016). Furthermore, a lot of marginalized and vulnerable communities, especially Indigenous peoples, directly depend on healthy ecosystems for their food, water, shelter and cultural identity. However, a thorough and integrated strategy that tackles the underlying causes of environmental degradation, involves stakeholders at all levels, and takes into account various knowledge systems and viewpoints needed for effective ecosystem restoration. Acknowledging the significance of Indigenous knowledge and customary ecological methods is part of this, since they provide insightful information on resilient communities, ecosystem dynamics, and sustainable resource management. We can protect ecological integrity, improve biodiversity conservation, advance human well-being, and lessen the effects of climate change by funding restoration projects. Prioritizing and accelerating restoration efforts is essential, as is embracing creative solutions and collaborations that maximize the combined knowledge and experience of many stakeholders.

Indigenous Knowledge and its relevance

To properly restore ecosystems, a comprehensive approach is required, and this understanding must take into account the concept of “Indigenous knowledge” and its importance to these efforts. Indigenous knowledge is the body of information derived from generations of close and ongoing interactions between Indigenous peoples and the natural environment. It includes customs, beliefs, practices, and wisdom. Indigenous knowledge systems, anchored in profound spiritual ties to the land, provide distinctive perspectives on resource management, ecosystem dynamics, and sustainability. Indigenous stakeholders needed to be consulted, according to the Society for Ecological Restoration (McDonald *et al.*, 2016). Proper engagement with Indigenous knowledge, partnerships that closely adhere to international declarations on free, prior, and informed consent, as well as extensive input and consultation at all stages from the Indigenous community, are all essential. The right to revoke permission must always be available to indigenous peoples (UN 2016).

Instead of being recognized as sovereign States with rights and obligations, indigenous peoples have been referred to as “stakeholders” (Latulippe and Klenk 2020). Thus, it is critical to create new relational terminology and viewpoints for practice and study, as well as to make room for Indigenous leadership. Therefore, acknowledging and include Indigenous populations in restorative ecology goes beyond simple "inclusion." It allows for the advocacy and contextualization of the experiences of Indigenous people (Quayle and Sonn 2019). Indigenous knowledge is important for restoration because it takes a comprehensive

view of ecosystems as interdependent systems, where environmental health and human well-being are closely related.

Unlike conventional scientific approaches, which often focus on isolated components of ecosystems, Indigenous knowledge embraces a more comprehensive worldview that considers the interdependence of all living beings and their habitats.

Indigenous knowledge also highlights the significance of preserving harmony and balance with environment, acknowledging that human activities can have a significant impact on ecosystems and future generations. For generations, Indigenous people have been supported by traditional ecological techniques that improve soil fertility, water quality, biodiversity, and sustainability. Examples of these practices include agroforestry, rotational grazing, and fire management. Through the incorporation of Indigenous knowledge into restoration initiatives, professionals can leverage this vast reservoir of information to guide choices, improve project results, and foster enduring sustainability.

Furthermore, community-based governance, resilience, and flexibility are frequently given top priority in Indigenous knowledge systems; these are crucial concepts for successful ecosystem restoration in the face of environmental change.

Indigenous peoples have evolved complex coping mechanisms to deal with environmental uncertainty. These include traditional ecological calendars, seed storing, and seasonal migration. These tactics can be useful in adjusting restoration plans to uncertain and changing conditions. Indigenous knowledge complements scientific approaches and improves the efficacy and sustainability of restoration initiatives by providing a comprehensive, place-based approach to understanding and recovering ecosystems (Fischer *et al.*, 2021). Significantly more work must be done to lessen the challenges to Indigenous cultural integrity and to allow Indigenous leadership to be prioritized in restoration ecology (Fischer *et al*., 2021).

Restoration practitioners may capitalize on the wisdom of traditional ecological techniques to address the complex challenges of environmental degradation and create resilient, thriving ecosystems by valuing Indigenous knowledge and working respectfully with Indigenous populations for future generations.

Key Pathways to effectively integrate Indigenous Knowledge into Ecosystem Restoration

Respective Collaboration and Knowledge Sharing: Restoring ecosystems while incorporating indigenous knowledge requires a cooperative strategy that honors and respects the understanding of native populations. In order to ensure that the voices of indigenous communities are heard and their priorities are taken into consideration, this approach entails acknowledging and respecting the knowledge, culture, and rights of these communities as well as the significance of their traditional ecological knowledge in ecosystem restoration efforts. It also entails forming partnerships and fostering long-term relationships based on mutual respect, facilitating two-way knowledge exchange between indigenous knowledge holders and restoration practitioners, and being culturally sensitive and aware of the protocols (Weir *et al.*, 2024). Permission from customs and sacred sites of indigenous communities, funding capacity-building programs to enable them to take the lead in and contribute to ecosystem restoration projects; modifying restoration plans in response to input from native communities and data from ecosystem monitoring programs; and, lastly, pushing for laws that acknowledge and encourage the

incorporation of native knowledge into ecosystem restoration procedures.

Deep listening and appropriate participation are the main tools needed to share knowledge in a way that supports Indigenous leadership and keeps ecological and cultural integrity intact. Furthermore, successful partnerships require the acknowledgement and recognition of Indigenous sovereignty over data and knowledge, as well as the express right "to own, control, access and possess data that derive from Indigenous People and which pertain to their members, knowledge systems, customs or territories" (Kukutai *et al*., 2000).

By adhering to these guidelines, cooperation and information exchange can successfully combine indigenous knowledge with ecological restoration, producing more comprehensive, culturally appropriate, and long-lasting results.

Adaptive Management and place-Based Approaches: Adaptive management is the process of changing strategies after taking into account lessons learned from the results of management actions. Adaptive management can assist in incorporating feedback from indigenous groups and responding to shifting environmental conditions through ongoing learning, adaptability, and cooperative decision-making when integrating indigenous knowledge into ecosystem restoration. Place-based methods take into account the distinct social, cultural, and biological background of every restoration site. Through cultural mapping, tailored methods, community empowerment, and interdisciplinary collaborations, it is crucial to take into account the unique links that indigenous populations have with their natural lands and waters when integrating indigenous knowledge.

Subsequently, land managers have received calls to recognize and take into account Indigenous viewpoints when making decisions (Aronson *et al*., 2020). The United Nations (UN) Declaration on the Rights of Indigenous Peoples (UNDRIP) takes a broader view of these debate topics about consultation, the need for respect, and inclusive decision-making procedures with Indigenous peoples. With special attention to the need for dialogue with Indigenous communities regarding their alignment with the UN Sustainable Development Goals (SDGs), the UNDRIP was created to support the protection and upholding of the rights of Indigenous peoples (Smith and Mitchell 2020).

Restoration practitioners can successfully incorporate indigenous knowledge into ecosystem restoration efforts by combining adaptive management with a place-based strategy. This method produces more culturally appropriate, resilient, and sustainable results.

Policy and Institutional Support: It is crucial to legally recognize indigenous land tenure and decision-making authority over the management of natural resources. Within national laws and regulations, governments might include provisions for the incorporation of indigenous knowledge into policies for environmental management and restoration. Requirements for cooperation and engagement with indigenous groups during the decision-making process may fall under this category. Establishing institutional frameworks will help indigenous groups, governmental organizations, non-governmental organizations, and other stakeholders in ecosystem restoration work together more easily. The aforementioned methods have to guarantee the significant involvement of indigenous peoples at every phase of the planning, execution, and oversight process. Institutions ought to assist in recording and conserving indigenous knowledge on the maintenance and repair of ecosystems. Creating archives, databases,

and repositories can help preserve traditional ecological knowledge for next generations.

Prioritizing the rights of Indigenous peoples may increase the chance of achieving global conservation goals, which will benefit everyone on Earth. Greater co-benefits are contingent upon not only respecting traditional knowledge systems but also directly emphasizing Indigenous leadership in restoration efforts, in addition to rights (Latulippe and Klenk 2020). **Building Capacity and Empowerment**: Through relationship-building, recognizing community needs and priorities, and including community members in restoration processes, this intended to harness the wisdom, traditions, and practices of indigenous groups to restore and sustainably manage ecosystems. In order to give training, resources, and support for the advancement of their capacity, it is easier for scientists to communicate with and exchange knowledge with indigenous knowledge holders when they are aware of their distinct viewpoints, beliefs, and practices.

for ecosystem restoration effort.

Case Studies and Best Practices

The Rights-of-Whanganui River, Aotearoa Nature Method: According to Harden-Davies *et al*., (2020), the legal argument known as the "rights of nature" has developed in environmental law to change the legal status of the environment from that of an object (such as a forest or river) to that of an autonomous legal person. Indigenous peoples' knowledge systems have frequently been found to have elements of the foundations of natural law. Indigenous peoples have implemented this idea of governance through ancestral link so that environmental protection remains a personal responsibility rather than depending on it being mandated by a constitution (Norman 2017). One of the first rivers in the world to be acknowledged as an indivisible living entity was the Whanganui River (Brierley *et al*., 2019) by being given personhood in 2017 by the New Zealand parliament's Te Awa Tupua Act. In addition to being used to establish responsible local resource management and restoration, this legal argument may eventually be utilized to help develop appropriate consequences for environmental misuse.

Osun-Osogbo River in the state of Osun: In a similar vein, this ecosystem's concept of the sacred groove is a method based on traditional knowledge. Land or water features that hold particular spiritual importance for individuals and groups are referred to be "sacred grooves" (Verschuuren *et al*., 2010). The biodiversity of the ecosystem has been successfully protected in the Osun-Osogbo groove, a UNESCO World Heritage Site, as well as numerous other sacred grooves in southwest Nigeria. It is becoming more widely acknowledged as a conventional method of community-based conservation, even though it protects places that are deeply significant to the locals' cultures and religions. When compared to both degraded and primary forests in southwest Nigeria, Osun Osogbo had the highest species richness and the highest number of endangered species (Onyekwelu and Olusola, 2014).

CONCLUSION

Through acknowledging Indigenous knowledge as an additional valuable source of wisdom in the context of ecosystem restoration, we can progress toward more egalitarian, inclusive, and sustainable methods of environmentally responsible practices. This not only makes restoration efforts more successful but also builds cultural resilience and improves linkages between Indigenous groups and the larger community. In addition, ecological resilience will be enhanced to promote cultural continuity, social justice, and a more holistic

approach to sustainability. This pathway holds promise for creating more inclusive and effective strategies for a sustainable future.

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COMPOSITION AND RELATIVE ABUNDANCE OF ICHTHYOFAUNA IN SEBORE RESERVOIR, MAYO-BELWA, ADAMAWA STATE, NIGERIA

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ABSTRACT

The composition and relative abundance of Ichthyofauna of Sebore reservoir at Mayo-Belwa, in Adamawa State of Nigeria was evaluated as part of bio-resources. Catches were collected from fishers using gill nets, traps, hooks and line of different mesh sizes ranging from 25mm to 185mm at the reservoir for a period of a year. A total of 1,855 fishes were obtained as samples. Identification of the Ichthyofauna revealed 12 families and 36 species while analysis of the percentage composition elucidated that the family Cichlidae has the highest relative abundance with 31.86% followed by the Claroteidae (9.60%) while the least was the family Notepteridae (1.40%). The fish species with highest relative abundance recorded during the study was *Coptodon zilli* (6.79%) followed by *Oreochromis niloticus* (5.49%) while the least abundant species was *Hippopotamyrus psittacus* (1.02%). It was concluded that Sebore reservoir is rich in both family and species composition and relative abundance of fishes, hence, proper management strategies are needed to be adopted to sustain the bio-resources of the reservoir.

Keywords: Ichthyofauna, Sebore reservoir, Composition, Relative abundance

INTRODUCTION

The freshwater fisheries resources of Nigeria are on the decline due to overfishing and inadequate management of the available water bodies (Usman *et al.*, 2019). For the sustainability of the bio-resources adequate information of the ichthyofauna, diversity and relative abundance of the water bodies are needed (Lawson and Olusanya, 2010). A good understanding of the fish species composition of water bodies is paramount for the sustainability of aquatic bio-resources (Sogbesan and Kwaji, 2018). Investigating the state of the fisheries relative to its composition of stocks is necessary for the proper management of aquatic resources for a long-term sustainability of catches (Nababa *et al.*, 2024); in other words in order to optimize the quantity that can be timely harvested without jeopardizing the fishing resources and biological or economic sustainability (Yusuf and Abdulkarim, 2015). This study was carried out to evaluate the composition and relative abundance of ichthyofauna as bio-resources in Sebore reservoir.

MATERIALS AND METHODS

Study Area

Sebore reservoir is located at Mayo-Belwa local government area (LGA), Adamawa State Nigeria. Mayo – Belwa LGA lies within Latitude 9° 3’ 0’ North; and Longitude 12° 3’ 0’ East. It covers an area of 1768km² (682.63 sq m) and is 75 km away from Yola, the state capital.

Sampling and Identification of Fish

The samples collection was done with the help of some fishers on monthly basis. Fish species caught were identified with the aid of keys and descriptions by Idodo-Umeh (2003); Balogun (2006) and (Olaosebikan and Raji, 2013). The study was carried out for a period of one year: from January to December, 2022, thereby covering both dry and wet seasons.

RESULTS AND DISCUSSION

The study indicated that a total of 1,855 fish belonging to 12 families and 36 species were recorded (Tables 1 and 2). The family abundance elucidated that the catch was dominated by Cichlidae (31.86) followed by Claroteidae (9.60%) and Mormyridae (9.54%), while Notoptereidae was the least abundant family with the value of 1.40% (Table 2).

The species relative abundance elucidated that the catch was dominated by *Coptodon zilli* (6.79%) followed by *Oreochromis niloticus* (5.49%) and *Oreochromis aureus* (5.01%), while *Hippopotamyrus psittacus* was the least abundant species with the value of (1.02%) as in Table 3.

Table 1: Checklist of Family and Species at Sebore Reservoir, Mayo-Belwa, Adamawa State, Nigeria

Family	Species
Alestidae	*Hydrocynus forskalii* (Cuvier, 1819)
	Hydrocynus vitatus (Casteha, 1861)
	Brycinus nurse (Rupell, 1832)
Arapaimidae	*Heterotis nilotius* (Cuvier, 1829)
Bagridae	*Bagrus bajad* (Forsskall, 1775)
	Bagrus docmak (Forsskall,1775)
Cichlidae	*Chromidotilapia guntheri* (Sauvage, 1882)
	Coptodon dageti (Thys van den Audenaerde, 1971)
	Coptodon zilli (Gervais, 1848)
	Hemichromis bimculatus (Gill, 1862)
	Hemichromis fasciatus (Peters, 1857)
	Oreochromis aureus (Steindachner, 1864)
	Oreochromis niloticus (Linnaeus, 1758)
	Sarotherodon galilaeus (Linnaeus, 1758)
Clariidae	*Clarias anguillaris* (Linnaeus, 1758)
	Clarias gariepinus (Burchell, 1822)
Clarotidae	*Auchenoglanis biscutatus* (Geoffrey Saint – Hillaire, 1808)
	Auchenoglanis occidentalis (Valenciennes, 1840)
	Chrysichthys auratus (Geoffrey Saint – Hillaire, 1808)
	Chrysichthys nigrodigitatus (Lacepede, 1803)
Cyprinidae	*Labeo coubie* (Rupell, 1832)
	Labeo senegalensis (Valenciennes, 1842)
Latidae	*Lates niloticus* (Linnaeus, 1762)
Mockokidae	*Synodontis batensoda* (Rupell, 1832)
	Synodontis budgeti (Boulenger, 1911)
	Synodontis schall (Bloch and Schneider, 1801)
Mormyridae	*Hippopotamyrus psittacus* (Boulenger, 1897)
	Hyperopisus bebe (Lacepede, 1803)
	Marcusenius senegalensis (Steindachner, 1870)
	Mormyrops anguilloides (Linnaeus, 1758)
	Mormyrus rume (Valenciennes, 1846)
	Petrocephalus bovei (Valenciennes, 1846)
Notopteridae	*Xenomystus nigri* (Gunther, 1868)
Schlibidae	*Parailia pellucida* (Boulenger, 1901)
	Schilbe intermedius (Rupell, 1832)
	Schilbe mystus (Linnaeus, 1758)

Table 2: Composition and Relative Abundance of Fish Family at Sebore Reservoir

Family	Number of Species	Percentage (%)
Alestidae	139	7.50
Arapaimidae	37	1.99
Bagridae	145	7.82
Cichlidae	591	31.86
Clariidae	149	8.03
Clarotidae	178	9.60
Cyprinidae	100	5.40
Latidae	33	1.78
Mockokidae	120	6.46
Mormyridae	177	9.54
Notopteridae	26	1.40
Schlibidae	160	8.62
Total	1,855	100.00

A total of 1,855 fishes were obtained during the study period consisting of 12 families and 36 species which were less than the findings of Agorua *et al.* (2019) who reported 24 families and 48 fish species at Oguta Lake, Imo State of Nigeria. The low number of families and species recorded from this study compared with that of Adeniyi and Akinwole (2016) at lower river Niger, Agenebode, Edo State and Agorua *et al.* (2019) at Oguta Lake Imo State, Nigeria probably due to the smaller size of the reservoir when compare to the rivers and lakes. However, the findings of this study were higher than the findings of Suleiman and Onma (2016) who reported 11 families and 30 species at Kaduna river, Kaduna State and Usman *et al.* (2019) who reported 6 families and 16 species at Mada river, Akwanga, Nasarawa State. The abundant fish species recorded in this study were *Coptodon* zilli (6.79%), *Oreochromis niloticus* (5.49%) and *Oreochromis aureus* (5.01%). It was observed that Cichlidae was the dominant family with relative abundance of 31.86% this corroborates the findings of Solomon *et al.* (2012) at lower river Niger, Idah, Kogi State and Agorua *et al.* (2019) at Oguta lake Imo State.

Table 3: Composition and Relative Abundance of Fish Species at Sebore Reservoir

Species	Number	Percentage
Hydrocynus forskalii	48	2.59
Hydrocynus vitatus	51	2.75
Brycinus nurse	40	2.16
Heterotis nilotius	37	1.99
Bagrus bajad	74	4.13
Bagrus docmak	71	3.67
Chromidotilapia guntheri	73	3.94
Coptodon dageti	56	3.01
Coptodon zilli	126	6.79
Hemichromis bimculatus	33	1.78
Hemichromis fasciatus	31	1.68
Oreochromis aureus	93	5.01
Oreochromis niloticus	102	5.49
Sarotherodon galilaeus	77	4.18
Clarias anguillaris	60	3.23
Clarias gariepinus	89	4.80
Auchenoglanis biscutatus	58	3.12
Auchenoglanis occidentalis	63	3.40
Chrysichthys auratus	27	1.46
Chrysichthys nigrodigitatus	30	1.62
Labeo coubie	61	3.29
Labeo senegalensis	39	2.11
Lates niloticus	33	1.78
Synodontis batensoda	41	2.21
Synodontis budgeti	36	1.94
Synodontis schall	43	2.31
Hippopotamyrus psittacus	19	1.02
Hyperopisus bebe	29	1.57
Marcusenius senegalensis	28	1.50
Mormyrops anguilloides	31	1.68
Mormyrus rume	37	1.99
Petrocephalus bovei	33	1.78
Xenomystus nigri	26	1.40
Parailia pellucida	51	2.74
Schilbe intermedius	50	2.70
Schilbe mystus	59	3.18
Total	1,855	100.00

CONCLUSION

The study has elucidated that the ichthyofauna of Sebore reservoir, Mayo – Belwa, Adamawa State is rich in both family and species composition and relative abundance of fishes. This calls for the sustainability of the fishery management of the reservoir in order to continue to protect and preserve the ecosystem. Findings from this study will assist in aiding strategies needed to be adopted to sustain the management and utilization of the ichthyofauna as bio-resources of the reservoir.

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FISH COMPOSITION AND RELATIVE ABUNDANCE OF CHAKAWA RESERVOIR, MAYO-BELWA, ADAMAWA STATE, NIGERIA

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ABSTRACT

A study of the fish composition and relative abundance of Chakawa reservoir, Mayo-Belwa, Adamawa State, Nigeria was carried out for a period of a year. Catches were collected from fishers at the reservoir using gillnets, traps, hooks and line and fishing gears of different mesh sizes ranging from 25mm to 185mm. A total of 1,315 fishes were recorded, consisting of 10 families and 23 species with the family Cichlidae having the highest percentage composition (29.96%) followed by the Clariidae (16.12%) while the least was the family Alestidae (2.81%). The high relative abundance of the fish species were *Coptodon zilli* (8.52%) followed by *Oreochromis niloticus* (7.30%) with the least abundant species being *Raiamas nigeriensis* (1.45%). Considering the relative less diverse composition of the fish population stock in the reservoir and observation made from site inspection, therefore, it is recommended that anthropogenic activities in Chakawa reservoir should be regulated in favour of the bio-resources.

Keywords: Fish species, Fish composition, Chakawa reservoir, Fish harvesting, Fish stock

INTRODUCTION

The inland fisheries of Nigeria are made up of over 200 species in the various freshwater bodies (Agorua *et al.,* 2019). Distribution and abundance of fish species are important variables of fish population dynamics' studies that will help in evaluating the effect of fishing on a fishery as a basis of fishery management decisions (Adeyemi *et al.,* 2010). Throughout Africa and Nigeria in particular, the occurrence of a large number of inland or freshwater reservoirs, lakes, rivers and other aquatic habitats such as swamps and flood plains, of different sizes and forms, and containing a wide variety of fish populations, have provided mankind with the opportunity to exploit fish for food, income and livelihoods in general for many centuries (Abubakar 2006). The fish resource in Nigeria, apart from being a major source of cheap and quality animal protein for rural dwellers and raw materials for some industrial activities as well as serving recreational purposes (Zira *et al.,* 2017). Important yardstick to fish species biodiversity have been identified as overfishing, habitat destruction, inversion of exotic species and pollution (Agorua *et al.,* 2019**).** This study was carried out to investigate the fish composition and relative abundnce of Chakawa reservoir, Mayo – Belwa, Adamawa State in Nigeria.

MATERIALS AND METHODS

Study Area

Chakawa reservoir is located at Mayo - Belwa local government area, Adamawa State Nigeria. Mayo – Belwa LGA lies within Latitude 9° 3' 0' North and Longitude 12° 3' 0' East. It covers an

area of 1768km² (682.63 sq m) and is 75 km away from Yola, the state capital.

Sampling and Identification of Fish

The study was carried out for a period of one year, from January to December, 2022 covering dry and wet seasons. Fish samples collection was done with the help of some fishers on monthly basis. Fish samples were preserved in a plastic bucket with tightly – fitted cover containing 10% formalin which was taken to the field for fish sample preservation during collection after which it was moved to the laboratory for identification. Fish species caught were identified with the aid of keys and descriptions by Idodo-Umeh (2003); Balogun (2006) and (Olaosebikan and Raji, 2013).

RESULTS AND DISCUSSIONS

The study elucidates that a total of 1,315 fish belonging to 10 families and 23 species were recorded (Tables 1 and 2). The family abundance indicated that the catch was dominated by Cichlidae (29.96%) followed by Clariidae (16,12%) and Citharinidae (10.27%) while Alestidae was the least abundant family with the value of 2.81% as elucidated in Table 2.

Table 1: Checklist of Family and Species in Chakawa Reservoir, Adamawa State, Nigeria

Family	Species
Alestidae	*Brycinus nurse* (Rupell, 1832)
Bagridae	*Bagrus bajad* (Forsskall, 1775)
	Bagrus docmak (Forsskall,1775)
Cichlidae	*Coptodon dageti* (Thys van den Audenaerde, 1971)
	Coptodon zilli (Gervais, 1848)
	Oreochromis aureus (Steindachner, 1864)
	Oreochromis niloticus (Linnaeus, 1758)
	Sarotherodon galilaeus (Linnaeus, 1758)
Citharinidae	*Citharinus citharus* (Geoffrey Saint – Hillaire, 1809)
	Citharinus latus (Muller and Truschel, 1845)
Clariidae	*Clarias gariepinus* (Burchell, 1822)
	Heterobranchus bidorsalis (Geoffrey Saint – Hillaire, 1808)
	Heterobranchus longifilis (Valenciennes, 1840)
Clarotidae	*Chrysichthys auratus* (Geoffrey Saint – Hillaire, 1808)
	Chrysichthys nigrodigitatus (Lacepede, 1803)
Cyprinidae	*Raiamas senegalensis* (Steindachner, 1870)
	Raiamas nigeriensis (Daget, 1959)
Mockokidae	*Synodontis batensoda* (Rupell, 1832)
	Synodontis schall (Bloch and Schneider, 1801)
Mormyridae	*Mormyrops anguilloides* (Linnaeus, 1758)
	Mormyrus rume (Valenciennes, 1846)
Schlibidae	*Schilbe intermedius* (Rupell, 1832)
	Schilbe mystus (Linnaeus, 1758)

The species abundance elucidated that the catch was dominated by *Coptodon zilli* (8.52%) followed by *Oreochromis niloticus* (7.30%) and *Clarias gariepinus* (6.62%) while *Raiamas nigeriensis* was the least abundant species with the value of (1.45%) as shown in Table 3.

Table 2: Percentage of Fish Family Recorded in Chakawa Reservoir

Family	Number	Percentage (%)
Alestidae	37	2.81
Bagridae	109	8.29
Cichlidae	394	29.96
Citharinidae	135	10.27
Clariidae	212	16.12
Clarotidae	52	3.96
Cyprinidae	55	4.19
Mockokidae	116	8.82
Mormyridae	76	5.78
Schlibidae	129	9.80
Total	1,315	100.00

The fish samples collected during the study consisting of 10 families and 24 species were less than the findings of Zira *et al.* (2017) who reported 15 families and 47 species in Kiri reservoir, Shelleng, Adamawa state, Nigeria and Abubakar (2006) who reported 15 families and 36 species in lake Geriyo, Adamawa State. In terms of the relative abundance in species, *Coptodon zilli* (8.52%) followed by *Oreochromis niloticus* (7.30%) both of the family Cichlidae were the most dominant species. This was in agreement with the findings of Dan-Kishiya *et al.* (2012) who reported that the fish family Cichlidae was the most abundant species in lower Usuma reservoir; Abuja and Abubakar (2006) who reported *O. niliticusas* as the most abundant species in Lake Geriyo., Adamawa State. *O. niliticus* and Sarotherodon were also reported as the most abundant species in Lake Geriyo, Adamawa State by Abiodun and Miller (2005). Adeyemi *et al.* (2010) reported that *O. niliticus* was the most abundant fish species at Gbedikere lake, Bassa, Kogi State. The dominance of the cichlids could be attributed to their prolific breeding habit.

The Cichlids are found to breed about three to four times in the year (Abubakar, 2006). High catches and species identified were observed during the period of the study in dry season (March, 2022), this was in agreement with the findings of Meye and Ikomi (2008) in Urie creek at Igbide in Delta state who reported high catches in dry season. The reason for the high catches may be attributed to the ability of the fishers during the dry season, to access further parts of the fishing grounds because of decreased of water depth and increased available space which are otherwise inaccessible during the wet season.

Table 3: Percentage of Fish Species Composition in Chakawa Reservoir

Species	Number	Percentage (%)
Brycinus nurse	37	2.81
Bagrus bajad	58	4.41
Bagrus docmak	51	3.88
Coptodon dageti	76	5.78
Coptodon zilli	112	8.52
Oreochromis aureus	48	3.65
Oreochromis niloticus	96	7.30
Sarotherodon galilaeus	62	4.71
Citharinus citharus	72	5.48
Citharinus latus	63	4.79
Clarias gariepinus	87	6.62

Heterobranchus bidorsalis	61	4.63
Heterobranchus longifilis	64	4.87
Chrysichthys auratus	23	1.75
Chrysichthys nigrodigitatus	29	2.21
Raiamas senegalensis	36	2.74
Raiamas nigeriensis	19	1.45
Synodontis batensoda	55	4.18
Synodontis schall	61	4.64
Mormyrops anguilloides	37	2.82
Mormyrus rume	39	2.96
Schilbe intermedius	61	4.63
Schilbe mystus	68	5.17
Total	1,315	100.00

CONCLUSION

The result elucidates that a total of 1,315 fishes were sampled; 10 families and 24 species were identified at the Chakawa reservoir. *Coptodon zilli* and *Oreochromis niloticus* both are of the family Cichlidae. were the most abundant species while *Raiamas nigeriensis* of the family Cyprinidae was the least abundant species. High catches and species identified were recorded during the period of the study in dry season.

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FEEDING HABITS OF AFRICAN BUTTER CATFISH (*Schilbe mystus*, Linne, 1758) OF SEBORE RESERVOIR, MAYO – BELWA, ADAMAWA STATE, NIGERIA

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ABSTRACT

The feeding habits of African butter catfish (*Schilbe mystus*) a commercially important fish species at Sebore reservoir in Mayo-Belwa, Adamawa State, Nigeria were investigated for a period of a year. A total of 120 specimens collected from the reservoir were used for the study. *S. mystus* specimens were caught using gill nets of 50mm mesh size as the fishing gear. The *S. mystus* were preserved in ice crest to minimize any post-mortem changes. The viscera of each of the *S. mystus* were opened and the gut were removed and preserved in 4% formalin solution. Stomach contents were analyzed using the frequency of occurrence method. The Summary of stomach contents analyzed elucidated that the food items more frequently observed were zooplanktons **(**40.14%) and insects (22.93) while the least frequently observed food items were fish parts (1.97) and higher plant materials (1.27). Findings from this study indicated that *S. mystus* of Sebore reservoir were omnivorous in their feeding habits. From the feeding habits, *S. mystus* is recommended for further investigation as a potential candidate for aquaculture.

Keywords: Feeding habits, *Schilbe mystus*, stomach contents, omnivorous, Sebore reservoir

INTRODUCTION

The family Schilbeidae is a group of catfish species of which *Schilbe mystus*, also known as the African butter catfish is a key member (Idodo-Umeh, 2003). The family Schilbeidae is represented by four genera and eight species in Nigeria (Olaosebikan and Raji, 2013). The fish is widely distributed in Nigeria, it is found in rivers, clear water streams, lakes and some reservoirs, while it is more abundant during the rainy season than dry season (Idodo - Umeh, 2003). African butter catfish is a source of protein which serves as a first-class animal protein due to the tasty nature of its flesh and is eaten widely by many people, therefore provides essential amino acids which are not present in plant protein, it is also a beautiful species for aquarium (Mshelia *et al.*, 2014).

The knowledge of the food a fish consumes is key to understanding the life cycle of the fish and also a solution for practical challenges which can arise in fisheries management (Yusuf *et al.*, 2024).). Evaluation of the feeding habits of fish,

based on stomach contents analysis is a standard approach in fish ecology, as an important mean of investigating trophic relationship in aquatic ecosystem (Igejongbo, 2019). The stomach content analysis of food in the stomach of fish in their natural habitats is a yardstick for knowing what are to be fed to the species in captivity (Igejongbo and Busari, 2015). The aim of this study was to determine the food composition in the stomach of *Schilbe mystus* from Sebore reservoir using the frequency of occurrence method.

MATERIALS AND METHODS

Study Area

Sebore reservoir is located at Mayo - Belwa local government area (LGA), Adamawa State Nigeria. Mayo – Belwa LGA lies between Latitude 9°3'0'' North and Longitude. 12°3'0'' East; It covers an estimated area of 1768km² and is about 75 km away from Yola, the capital of Adamawa state.

Collection of Sample

Fishing was conducted at Sebore reservoir with gill nets of 50mm mesh size as the fishing gear. The nets were set by 3:30pm of each sampling day and were retrieved between 6:30am – 7.00am. Specimens were collected monthly for a period of a year, that is, from January to December, 2022. A total of 120 samples of *S. mystus* were used for the study. The fish specimens were washed with clean water and preserved in ice crest to minimize any post-mortem changes and taken to the laboratory at the Department of Fisheries, Modibbo Adama University, Yola for analysis of the stomach contents.

Laboratory Analysis of Specimens

The total length of the *S. mystus* specimens were measured in centimeters (cm) using a measuring board (meter rule) and weighed using an accurate digital scale in grams (g). The *S. mystus* body cavity were opened using a pair of scissors, beginning ventrally from the anus to the mouth as described by Yusuf *et al.* (2023). The visceral organs such as the liver, fat and other organs attached to the intestine and stomach were gently removed and emptied into a plastic dish. The length and weight of the stomachs were measured and recorded. Thereafter, the visceral organs were preserved in four per cent (4%) formalin solution to avoid any form of deterioration and contamination of the stomach contents Yusuf *et al.* (2024). The stomach contents were opened using a pair of scissors and the complete stomach contents were emptied into petri dish for examination and identification (Ikongbeh *et al.*, 2012).

The random samples of the stomach contents were taken and dropped on a slide (counting chamber) with the aid of a dropping pipette which served as the dropper and viewed under a light microscope. The general viewing were made with a binocular dissecting microscope stereo zoom total magnification of 100×. The stomach contents were studied and recorded. The stomach contents of each of the *S. mystus* specimens were identified, analyzed and recorded using the frequency of occurrence method as described by Balogun (2006). In the frequency of occurrence methods, all stomach containing food were recorded and expressed as the percentage of the total number of stomachs examined using the following formula;

$$p = (b/a) \times 100$$

Where:

a = Total Number of *S. mystus* examined with food items in the stomach

b = Number of *S. mystus* containing a particular food item

p = Percentage (%) occurrence of each food item

Statistical Analysis

Data obtained were analyzed using descriptive statistics in Microsoft Excel Windows 2016.

RESULTS AND DISCUSSION

Length and Weight of *Schilbe mystus* Specimens

A total of 120 specimens of *S. mystus* were collected and examined. The total length ranges from 12.7 – 22.5cm while the weight ranged from 16.9g – 80.6kg.

Degree of Fullness of Stomach of *Schilbe mystus*

From the data obtained from 120 specimens of *S. mystus* collected from the Sebore reservoir, 60 *S. mystus* representing 50.00% have their stomachs full with food items, while 49 *S. mystus* representing 40.83% were having half-filled stomachs and 11 *S. mystus* representing 9.17% were having empty stomachs (Table 1).

Assessment of Food Items

The *S. mystus* of Sebore reservoir feed on different food items, which include fish, fish parts, higher plants materials, insects, insects' parts, sand particles, unidentified worms phytoplanktons and zooplanktons; 27 food items were identified in the stomach contents of the *S. mystus* within the study period. The food items and percentages of the frequency of occurrence in the stomach contents of *S. mystus* from this study indicated that *Nauplius spp.* occurred more frequently (77.06%), while *Synodontis schall* (3.67%) occurred less frequently (Table 2). The summary of the stomach contents of the *S. mystus* elucidates that zooplanktons **(**40.14%) and insects (22.93%) occurred more frequently (Table 3).

Table 1: Number and Percentage of Stomach Fullness of *Schilbe mystus* from Sebore Reservoir

Degree of Fullness of Stomach	Number	Percentage (%)
Full Stomach	60	50.00
Half Stomach	49	40.83
Empty Stomach	11	9.17
Total	120	100.00

The relatively small size thus, the length and weight respectively of *S. mystus* were one of its genetic attributes. Idodo-Umeh (2003) reported that they could grow up to a maximum size of 300mm. However, Olaosebikan and Raji (2013) reported a maximum size of 350mm for *S. mystus*. In respect to the stomach contents of the *S. mystus* analyzed during the one year sampling period (January – December, 2022). The result elucidated that 90.83% had food in their stomach and only 9.17% stomachs had empty stomach.

The result indicated that there was availability of food in the reservoir and the food consumed had not been fully digested by the *S. mystus*. The result was not in agreement with the earlier findings of Ayoade *et al.* (2008) which reported higher empty stomach for *S. mystus* from two artificial lakes in southwestern Nigeria and suggested that it could be attributed to less availability of food and digestion of the consumed food (mainly protein), which begins from the stomach. The results indicated that the stomach contents of *S. mystus* of Sebore reservoir consisted mainly of food of animal origin (75.01%) corroborates with the findings of Idodo-Umeh (2003) who reported that *S. mystus* feed mainly on detritus, insects, and small fish.

Ayoade *et al.* (2008) reported that the diet of *S. mystus* consisted chiefly of fish, aquatic larvae, terrestrial insects, aquatic insects and crustaceans. The result from this study indicated that *S. mystus* from of Sebore reservoir has great preference for zooplanktons **(**40.14%) and insects (22.93%). However, phytoplanktons (16.33%) and higher plant materials (1.27%) were considered as primary food items in the study. The result corroborated the findings of Ayoade *et al.* (2008) who reported higher plants materials in the stomach contents of *S. mystus*. The stomach

contents of the *S. mystus* from of Sebore reservoir also contained sand/mud particles, which is in agreement with the reports of Akuna and Amachree (2019) for African butter fish, *Schilbe intermedius* from Agbura landing site, Bayelsa State, Nigeria.

Table 2: Analysis of Stomach Contents of *Schilbe mystus* from Sebore Reservoir

Food items	Frequency of occurrence method	
	Number of Stomachs	Percentage (%)
Fish		
Coptodon zilli	6	5.50
Mormyrus rume	21	19.27
Mormyrops anguilloides	19	17.43
Hemichromis fasciatus	7	6.42
Sarotherodon galilaeus	11	10.09
Synodontis schall	4	3.67
Fish parts		
Bones	13	11.92
Scales	12	11.01
Insects		
Anax spp.	78	71.56
Chaoburus spp.	74	67.89
Chironomus spp.	71	65.13
Cullicoides spp.	69	63.30
Insects parts		
Insects appendage	59	54.13
Other materials		
Sand particles	32	29.36
Unidentified worms	62	55.96
Plant Materials		
Remains of higher plants	16	14.68
Phytoplanktons		
Chlorella spp.	52	47.70
Diatomella spp.	61	55.96
Oscillatoria spp.	49	44.95
Phacus spp.	46	42.20
Zooplanktons		
Arcella spp.	73	66.97
Centropyxis spp.	67	61.47
Daphnia spp.	69	63.30
Diaptomus spp.	61	55.96
Moina spp.	84	77.06
Nauplius spp.	81	74.31
Rotaria spp.	76	69.72

Table 3: Summary of Stomach Contents of *Schilbe mystus* from Sebore Reservoir

Food Items	Frequency	Percentage (%)
Fish	68	5.34
Fish parts	25	1.97
Insects	292	22.93
Insects Appendage	59	4.63
Other materials	94	7.39
Plant Materials	16	1.27
Phytoplankton's	208	16.33
Zooplankton's	511	40.14
Total	1,273	100.00

The sand/mud particles were probably ingested accidentally with other food materials. However, Allison and Sikoki (2003) reported sand particles in the stomach of *Parailia pellucida* of the Schilbeidae family from Nun river but did not conside r sand particles as food. Due to the ease at which the *S. mystus* changes its diet, it has been called facultative feeder (Akuna and Amachree, 2019); opportunistic omnivore (Idodo-Umeh, 2003); opportunistic predator (Akuna and Amachree, 2019) and predator (Ayoade *et al.*, 2008).

CONCLUSION AND RECOMMENDATION

Findings from this study indicated that the *Schilbe mystus* of Sebore reservoir are omnivorous with higher preference for zooplanktons and insects as the majority of the food items observed in the stomach contents and are of animal origin while higher plant materials were the least preference of the food items observed in the stomach contents. *S. mystus* of Sebore reservoir are not rigid in their feeding habits hence can readily adjust due to availability of food items in the environment, therefore, it is recommended for further researches as a potential candidate for aquaculture.

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STATUS OF NYPA PALM (*Nypa fruticans* Wurmb.) IN A PROTECTED MANGROVE FOREST IN DELTA STATE

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ABSTRACT

Nipa Palm (*Nypa fruticans*), is an exotic species that thrives alongside the indigenous mangroves (*Rhizophora* spp.) within the brackish water enclaves of the Niger Delta of Nigeria. The palm has demonstrated a relatively higher capability of invasion, evidenced by its observed spread within the eastern Niger Delta of Nigeria. This situation has culminated in the gradual disappearance of the mangrove species and ecosystem services they provide. Information on extent of Nypa palm invasion within western Niger Delta ecosystem is limited. This study therefore examined the extent of Nypa palm invasion of mangrove forests in Delta State, using Ifie as a case study. A field survey was carried out to obtain population, heights and density of both Nypa palm and mangrove trees in the study area. Measurements were obtained from 12 quadrats of 20 m by 20 m each in dimension. Population ratio was 1:90 for *Nypa* and *Rhizophora* speciesrespectively. The mean height were 0.8 m and 47.2 m respectively for Nypa palm and Rhizophora spp. while the mean densities were 2 and 296 species/hectare for Nypa and *Rhizophora* spp respectively. One-paired t test revealed that there was a significant difference between the population of *Nypa fruticans* and the mangrove trees at $p<0.05$. This study indicated a possible reduced colonisation capacity of the Nypa palm within the study area. This study recommends the establishment of more mangrove conservation sites to discourage the growth of *Nypa fruticans*.

Keywords: Mangroves, Niger Delta, *Nypa fruticans*, *Rhizophora spp*, Nigeria

INTRODUCTION

Mangrove forested areas were previously regarded as the wastelands. Increase in knowledge and research findings in recent pasthave however resulted in the gradual obliteration of that notion. Patrick Jr (1994), James et al (2013). In-depth research into indigenous knowledge of local people has also contributed to a complete paradigm shift regarding the mangroves (Longépée *et al*., 2021). Mangroves are currently recognised for their resourcefulness, in terms of the services rendered to the entire ecosystem. Favourable sites for habitat and nursery for several microfauna/ fauna is among notable services they rendered (Ochoa-Gómez *et al.,* 2019). Mangroves have been known to provide ecosystem regulatory and protection roles of coastal erosion prevention and carbon sequestration (Inoue, 2019; Bimrah *et al.*, 2022). Mangroves have benefitted local people, through the provision of food and livelihoods, for several decades previously, thereby resulting in the sustenance of the local people (Numbere, 2018). The importance of mangrove forests should not therefore be underestimated, as their services form a critical linkage to the sustenance of all components of the vulnerable ecosystem of the Niger Delta.

The mangrove forest in Nigeria, being the largest in Africa, has been enveloped by ongoing global environmental degradation due mainly to anthropogenic disturbances. These disturbances are attributable to the population increase and subsequent impact. The basic requirements of the satisfaction of the needs of humans such as food and shelter amongst others, has formed the basis for this ongoing degradation. The unsustainable manner in which these are carried out culminates

in degradation and destruction. A notable consequence of the aforementioned is the gradual and consistent colonisation of the mangrove forested areas by the Nipa Palm (*Nypa fruticans*). Nipa palm is reported to have tremendously overtaken mangrove forest areas in Nigeria, increasing about seven times from 2007-2017 (Nwobi, *et al.,* 2020; Nwobi *et al.*, 2021).

Nipa Palm (*Nypa fruticans*) is an exotic palm which thrives in areas which play host to mangrove forests. Brackish water and tidal submergence conditions are notable characteristics of these areas. Nipa palms grow within a wide range of coastal environments such as tidal flats, creeks and a range of others. Nipa palm thrives optimally in clayey soil and its seeds adapt efficiently to inconsistent submergence by water (Hossaine and Islam, 2015). The range of Nipa Palm growth exceeds that of the mangrove, such that it grows more inland than the indigenous mangroves. Furthermore, Nipa palm and mangroves possess similar reproductive capabilities of being viviparous. Their resemblance to other regular palms is not in doubt; however, its branches emanate directly from the ground and not from a central stem like other palms (Duke, 2006). Aside from Nipa palm, other plants that have been reported to associate with mangrove include mangrove grass (*Paspalum vaginatum*), Mangrove fern (*Acrositcum aureum*) and wild palm (*Phoenix reclinata*). None, however is as invasive as the Nipa palm (Izuchukwu Uche, 2023).

Nipa palm is a native to the coastal areas of the Indian and Pacific Oceans (Nwobi *et al.,* 2020). It was introduced into Nigerian at Calabar estuary, in 1906, when it was introduced as a plantation plant, to serve the purpose of aesthetics and coastal erosion prevention (Okugbo *et al.,* 2012). The Nipa palm's ability to carry out speedy spread and colonisation is attributed to several of its inherent characteristics. For instance, the seeds of Nipa palm are capable of being water borne for long distances upstream In addition, its relative lack of use by the local population, because of its inability to perform the similar critical ecological services performed by the indigenous mangroves (Chima and Larinde, 2016), but which provides an opportunity for its consistency in growth relative to its relatively degraded mangrove counterparts (Isebor *et al.,* 2001, Nwobi *et al.,* 2020). Logging activities to meet the demands for fuelwood and wood for buildings, serve as selective harvesting drivers leading toin mangrove forest degradation in Nigeria. Aside from the invasive nature of the Nipa palm, another major challenge is.

The vast resources of the mangroves and its associated services, in view of the aforementioned, pose the risk of being completely overrun if urgent measures were not taken. The preservation of the integrity of the Nigerian mangrove forest cannot be overemphasized, particularly as it rank the largest in Africa. In addition, the ecosystem of the Niger Delta is globally recognised as a hot spot for biological diversity (Ogbeibu *et al.,* 2023). The sustainable management of the mangrove forest, therefore is critical to the survival of the flora, fauna and humans within the Niger Delta environment.

Several solutions have been proffered for the stalling of Nipa palm invasion, however with limited results. Developing strategies on ensuring nipa palm invasion is dependent on relevant information which are currently insufficient. Several studies have been carried out on mangroves and Nipa palm. For instance, Nwobi *et al*. (2021) examined the Nipa palm stand patterns. Udofia udo (2004) examined the local utilisation of Nipa palms. Nwobi *et al.* (2020) examined nipa palm invasion through a period of 2007-2017 across the entire Niger Delta. Asuk *et al*. (2018) examined Nipa palm encroachment in the eastern section of the Niger Delta. Numbere and Moudingo (2023) examined strategies for the management of Nipa pam across west and central Africa.

Studies on Nipa palm invasion on smaller sites for the purpose of tracking likely location-

specific drivers are limited. Generally, the need for collection of baseline data on this in smaller areas in extremely necessary. In addition, research on the aforementioned within the Niger Delta environment, especially the western section is sparse. Nwobi *et al.* (2020) affirmed that the Niger Delta environment was understudied. The need to obtain actual data rather than estimates through actual fieldwork is of relevance in providing solutions (Nwobu *et al.*, 2012). It is particularly important as a proper understanding the situation can only be efficiently achieved through the observation of field situations at smaller scales. This is necessary, as it brings to the fore the possibility of the discovery of the location specific drivers of Nipa palm encroachment. These relevant data will serve as a bridge for proffering realistic and sustainable strategies of ameliorating the nipa palm colonisation. The aim of this study therefore is to assess the extent of Nipa palm colonisation within a peri urban mangrove forest in Delta state, Nigeria.

MATERIALS AND METHODS

The mangrove forest assessed for this study is located within the Falcorp mangrove conservation site in Ifie community, Delta State, Nigeria. Ifie community forms a part of the Warri - Effurun metropolis. The coordinates of the arelatitudes 5º 31′N and 5º 34′ N and longitudes 5º 41′ E and 5º 44′E. The climate of the community is influenced by the Tropical equatorial climate, characterised by the wet and dry seasons and a mean annual temperature of 31º C (Efe, 2007). The socioeconomic activities carried out in the area include farming, fishing, general commercial activities. The community also plays host to several oil exploratory and refining companies.

Vegetation data were taken for both Nipa palm and mangroves. Species composition, population, height and species density were taken from 12 plots of 400 sq meters each (20 m X 20 m). Species density was calculated based on the formula of number of individuals of a species per unit area. Only heights of the tallest trees were taken. They were taken with the use of a clinometer. Student T test was used to assess significant differences in population and heights between mangroves and Nipa palm species. Analysis of variance conducted to determine difference between heights of mangroves and Nipa Palm.

RESULTS AND DISCUSSION

The mangroves of the study area were identified to be *Rhizophora spp* (*Rhizophora racemosa, Rhizophora harrisonii*). This is line with a previous study (Akpovwovwo and Gbadegesin, 2022). *Nypa fruticans* occurred in only one plot. On the other hand, stands of *Rhizophora* spp were seen occurring within the remaining eleven plots. The population of the various species of mangroves and *Nypa fruticans* are shown in Table 1. The heights of the tallest mangrove tree within the plots are seen to range from 20 to 68m. These heights are much higher than the highest heights observed by Numbere and Camillo (2017) in a study conducted in a section of the Niger Delta. The only stand of *Nypa fruticans* measured 10 m in height, being the lowest of both species within the study area. Species density is highest among the *Rhizophora* spp and lowest for the *Nypa fruticans*.

Table 2 shows species density, for assessing the condition of mangroves, adapted from Mursalim, *et al* (2020). Parida *et al.* (2020) noted that mangroves characterised by higher densities have been observed to enhance sediment accretion. Table 2 shows that the density of both the *Rhizophora* spp and the *Nypa fruticans* fall within the category of being a very dense and in good condition. This is understandably so as the site is a designated mangrove protected area. The general categorisation based on species densities (Table 2), however is suggestive of the ongoing pressure emanating from anthropogenic activities occurring at the periphery of the site. The implication of this is the consideration of the setting up of a buffer zone when siting

conservation areas. The legislation of such sites should be recognised by Government to ensure compliance by all stakeholders involved such as land owners, businesses and government establishments. The density for *Rhizophora* spp however falls lower than the range observed by Akpovwovwo (2020), in which this site formed a part of the study area. This is suggestive of a decline in the density of the Rhizophora spp. This further confirms the increasing influence of human activities within and around the study area

Table 1: Vegetation measurements for *Nypa fruticans* and *Rhizophora* spp in the study area

	Population		Species Density (species/ Ha)		Height (m) of Tallest Tree/ Plot	
Plot	***Nypa fruticans***	***Rhizophora spp***	***Nypa fruticans***	***Rhizophora spp***	***Nypa fruticans***	***Rhizophora spp***
1	1	0	25	0	10	0
2	0	22	0	550	0	46
3	0	14	0	350	0	58
4	0	12	0	300	0	54
5	0	13	0	325	0	60
6	0	9	0	225	0	56
7	0	10	0	250	0	34
8	0	12	0	300	0	60
9	0	9	0	225	0	45
10	0	14	0	350	0	20
11	0	15	0	375	0	68
12	0	12	0	300	0	65
Mean	0.1	11.8	2	296	1	47
Total	1	142				

Source: Fieldwork (2023)

.

Table 2: Criteria for species density

Mangrove Condition	**Criteria**	**Density (Tree / hectare**	**Density (Tree /hectare) for study site**
Good	Very Dense	>= 1500	3550
	Dense	>= 1000 – 1500	
Damaged	Rarely	< 1000	

Source: Mursalim *et al* (2020)

The population of both the *Nypa fruticans* and the *Rhizophora* spp is a clear indication of the significant difference in population, as seen in Table 1. Among 12 quadrats, only one stand of *Nypa fruticans* was observed. The Student T test result (t value= - 7.865, P(sig.) = 0.000) showed significant difference between the tree heights of the *Rhizophora* spp and *Nypa fruticans* at $p < 0.05$ significance level (Table 3). The ANOVA test result (F = 0.003, P(Sig.) = 0.955) showed no significant difference in the heights of the *Rhizophora* spp stands in the study area at the P<

0.05 significance level. This is indicative of uniform conditions within the study area (Table 4).

Table 3: Student T test result for significant difference between heights of *Nypa fruticans* and *Rhizophora* spp in Ifie community, Delta State, Nigeria

***Nypa fruticans_Rhizophora* spp**	**Paired Differences**					**T**	**df**	**Sig. (2-tailed)**
				95% Confidence Interval of the Difference				
	Mean	Std. Deviation	Std. Error mean	Lower	Upper			
Pair 1	-46.333	20.406	5.891	-59.299	-33.368	-7.865	11	0.000

Source: Author (2023)

Table 4: Results of ANOVA test for significant difference of heights among stands of Rhizophora species in the Ifie community, Delta State, Nigeria

ANOVA					
	Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
Between Groups	1.485	1	1.485	0.003	0.955
Within Groups	4464.182	10	446.418		
Total	4465.667	11			

Source: Author (2023)

The correlation result (r = 0.0536, P(sig)= 0.072) shows that there is no significant relationship between the density and the height of the tallest trees within the study area. Heights of trees is suggestive of the presence of favourable conditions for tree growth. The lack of correlation between the density and the tallest heights has ruled out the possibility of density, being a driver of optimal growth for mangroves. This implies that density and by consequence competition for nutrients and sunlight do not significantly impact the optimal growth of mangroves. It is therefore likely that a combination of other unknown factors which are may be location – specific are responsible. A similar test of correlation could not be replicated for the *Nypa fruticans* because of its near absence based on its very low population value.

The findings of this study show the occurrence of *Nypa fruticans* within a protected area. This thereby confirms its invasive ability, despite the near absence of the occurrence of disturbance, as it is a protected site. This is inview of an assertion by Nwobi *et al* (2021), noting that *Nypa fruticans* were observed to occur more in disturbed sites. Corroborating this, Harun rashid *et al* (2009),

Ukpong (2015) affirmed a connection between mangrove depletion and *Nipa fruticans* colonisation. Nwobi *et al* (2021) also noted that *Nypa fruticans* occurred less in areas that were farther hinterland, owing to the long distance away from the point of introduction by the coast. The occurrence of *Nypa fruticans* within a protected site, further suggests the possibility of its imminent invasion of the area. Further studies are required to understand the drivers of its spread in areas with limited disturbance. Furthermore, long term studies should be carried out to ascertain the rate and spread of *Nypa fruticans* within this particular protected site over the long term.

Table 5: Result of correlation of density and tallest tree height for *Rhizophora* spp

Variable		Density	Height
Density	Pearson Correlation	1	.536
	Sig. (2-tailed)		.072
	N	12	12
Height	Pearson Correlation	.536	1
	Sig. (2-tailed)	.072	
	N	12	12

CONCLUSION

This study has shown the possibility of *Nypa fruticans* spread within a protected mangrove forest. The protected status of the study site, is seen not to be a limiting factor in this study. This situation may also be an indication of ongoing disturbance which needs to be curbed. It could also be as a result of the operation of certain factors which may be location specific or otherwise. Further research needs to be carried out over time periods in the future to examine and determine the possibility of its spread and the likely drivers within protected mangrove sites. It is therefore being recommended that increased awareness on the dangers of *Nypa fruticans* spread among all stakeholders, ranging from the local people to private and public sectors. There should be proper legislation and regular monitoring of conservation sites. In view of this, collaboration between the public and private sectors should be encouraged. More areas should be designated as conservation sites to stall the spread of *Nypa fruticans*. Furthermore, alternative sources of income should be provided for the local people. More interdisciplinary research should be carried out to further develop strategies in managing the mangrove forest and stalling the invasion of *Nypa fruticans.*

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IMPACT OF ORGANIC SOIL AMENDMENTS ON FUNGAL POPULATION AND GERMINATION OF MAIZE SEEDS IN LEAD-CONTAMINATED SOIL

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ABSTRACT

Proliferation of industrial and other anthropogenic activities has led to an increase in heavy metal contamination of agricultural soil, elevating the risk of heavy metal (especially, lead) toxicity to all life forms. It is therefore imperative to develop effective bioremediation techniques for soil remediation. Cow dung and compost (*Tithonia rotundifolia* and poultry droppings) were added at 30 t/ha to lead contaminated soil. Abundance of heavy metal associated fungi in the contaminated soil was determined through pour plate isolation method using Potato Dextrose Agar. The effect of lead contamination and soil amendments was also determined on maize seed germination in the laboratory using Petri dishes in three replications. Heterotrophic fungal count in lead-contaminated soil decreased as Pb concentration increases. The abundance of soil associated fungi declined with an increase in lead concentration. It ranged from 3.2×10^3 to 0.00 CFU/mL in soils containing 0.36 g/kg lead and 63.01 g/kg lead, respectively both amended with cow dung. *A. fumigatus, A. flavus, A. nudulans, A. tamarii, A. uvarum and A. terreus* were the fungi species isolated from contaminated soil samples. *A. fumigatus and A. flavus* were the most prominent. *A. fumigatus* was able to survive at 100% concentration of lead amended with compost, 75% lead concentration amended with cow dung, 25% lead concentration amended with cow dung, and 100% lead concentration without amendment. Percentage germination of maize seeds also decreased with higher concentrations of lead in contaminated soil. High percentage germination (81.81 and 80.00) was observed in the control soil, and on 0.36 g/kg lead-contaminated soil, amended with cow dung, respectively. Organic fertilizers could be adopted to develop an efficient, cost-effective, and readily accessible bioremediation strategy for soil remediation, especially for the production of maize.

Keywords: Bioremediation, Lead contamination soil, Maize, Fungi, Compost, Cow dung

INTRODUCTION

Maize (*Zea mays* L.) is one of the most important annual cereal crops in the world. It is a source of food and nutrition for several households in Nigeria (Ogunniyi *et al*., 2021). Maize contributes more to food security, poverty eradication and the Gross Domestic Products of Nigeria than other cereal crops, such as sorghum and millet (Adeagbo *et al*., 2021). In addition, maize is easily processed into several forms of products for both human and livestock consumption (Ogunniyi *et al.*, 2021). The value chain of maize (especially, postharvest processes) significantly contributes to job creation and overall economic development of the Country. However, maize production is affected by several environmental factors, especially, the nature and conditions of soil (Riccetto *et al.*, 2020), which determines the yield potentials of specific soil types. Contamination of soil with heavy metals reduces maize-yield potential and limits the economic significance of the crop.

The overall quality of the soil environment influences the quality of crop production. Pollution of the biosphere by heavy metal contamination, through domestic, agricultural and industrial activities has resulted in a serious problem thereby posing threat on safe or healthy utilisation of soil (Igwe *et al.*, 2005; Gravand *et al.*, 2021). Industrial waste, fertilizer application, pesticide utilization and the disposal of untreated metal-contaminated sewage continually contribute to heavy metal

accumulation and cytotoxic tendencies of soil (Herland *et al.*, 2000). Although, some biological heavy metals like Cu, Zn, Fe and Ni could be tolerated in minute quantities by plants, however, excessive or accumulated amount of these metals pollute the soil, which in turn becomes a threat to all forms of life, including plants, microorganisms, and animals, at varying degrees of toxicity (Gravand *et al.*, 2021; Mirhosseini *et al.*, 2021).

Lead is one of the potent environmental contaminants of all the heavy metals found in soil, disrupting or inhibiting several ecological, environmental and evolutionary processes in the microsphere. This alters the balance of microbial community, influences their niche functionality and affects the overall productivity of contaminated soil (Sofy *et al.*, 2020; Sun, X., Sun, M., Chao, Y. *et al.* 2023). Lead is one of the raw materials used in the production of ceramics, fertilizers, writing materials and batteries. It is also found in different products like paints, dyes, rubber products, gasoline, paper-prints and pesticides. Due to lead's ubiquity, soil is unwittingly contaminated by lead products, accumulating to toxic levels and significantly limiting the potentials of soils for healthy crop production (Sangeetha *et al.*, 2021).

Lead toxicity has been associated with poor agronomic performance of maize (Sofy *et al.*, 2020), especially in developing countries like Nigeria, where waste management systems are inefficient. This limits the yield and economic potential of the crop. Several heavy metal bioremediation techniques have been proposed over the years, these include bioslurping, bioventing, biosparging, phytoremediation, biofiltration, bioaugmentation, bio-stimulation and compost-remediation, which involves the use of organic fertilizers (da Silva *et al*., 2020). Fertilization with manure could improve the microbial quality of soil and encourage the growth of lead-degrading or solubilising microorganisms. This research work therefore investigates the effect of cowdung and compost on bioremediation of lead contaminated soil for the purpose of maize production.

MATERIALS AND METHODS

Collection and preparation of soil samples

Lead contaminated soil samples were collected from the Crop Physiology section of Environmental Biology unit of the Department of Crop Protection and Environmental Biology (CPEB), University of Ibadan, Oyo State, Nigeria. The uncontaminated soil samples was used to prepare the different soil mixtures for germination test. This was collected from Crop garden Department of Crop Protection and Environmental Biology, University of Ibadan. The soil samples were sieved to remove extraneous materials like, stone, plant residues and other non-soil materials. Samples were thereafter pre-mixed at different levels ; 0%, 25%, 50%, 70%, and 100 % with lead contaminated soil. Mixed soil samples were subsequently analysed for lead concentration.

Determination of lead concentration

Compost samples were taken from both contaminated and uncontaminated soils for analysis. They were crushed to generate fine particles. Subsequently, 1 g of soil sample from each treatment was weighed into labelled glass bottles; 10 mL nitric acid (65% HNO3) was added to each soil sample. Thereafter, 7.5 mL Hydrochloric acid (37% HCl) was added to the initial digested sample and the mixture was refluxed for 2 hours (Hurdebise *et* al., 2015; Castro-Bedriñana *et al.*, 2021). The resulting product was allowed to cool, then each of the samples was sieved using whatmann No. 1 filter papers. The retained solute was made up to 100 mL in Erlenmeyer flask and the level of lead contamination therein was determined using an Atomic Absorption Spectrophotometer (VGP210 BUCK Scientific Model). Standard blank method, duplicate samples

and control standard were used to ensure analytical precision. Lead concentration (expressed in mg/kg) in the samples were extrapolated from standardised lead (Sigma-Aldrich) calibration curve (Castro-Bedriñana *et al.,* 2021). The Pb concentrations were between 360.20 - 63,006 mg/kg in the soil mixtures.

Organic amendments and isolation of fungi from treated soil

Two organic fertilizers: cow dung and compost (*Tithonia rotundifolia* and poultry droppings), also obtained from Crop Physiology section of CPEB were added to soil mixtures at 30 t/ha each as soil amendments. It was a factorial experiment with five treatments.

Fungi associated with the soil samples were cultured in the laboratory to determine population at different levels of lead contamination. The microbial populations in the samples were enumerated using serial dilution and subsequent pour plate method following the procedure of Asadu *et al*., (2015). To reduce the propagules, 1 g of each soil sample was added to 9 mL of sterile distilled water to generate a 10^{-1} dilution. The resultant mixtures, in each case, was thoroughly mixed and further diluted up to 10^{-4} with sterile distilled water. One milliliter aliquot of the 10^{-2} and 10^{-4} dilutions of each sample was thereafter introduced into Petri dishes and 15 mL sterile Potato Dextrose Agar was dispensed into the plates and swirled gently to evenly distribute the sample. Inoculated plates were incubated at 28±2°C for 3-4 days. Thereafter, the growing colonies were counted and expressed as colony forming units per gram (CFU/g) of the samples (Monda *et al*., 2020). Microbial colonies were then sub-cultured to obtain pure cultures.

Fungi identification

To characterise the morphological properties of the isolates, fungal cultures on plates were examined for their cultural characteristics, strains were also prepared for microscopic observations. Growing tip (mycelia strands) of each strain was picked with a sterile inoculating needle and place in a drop of lactophenol cotton blue stain on a slide. A second, sterile inoculating needle was used to tease the mycelial strands, the preparation was then covered with a cover slip. Prepared slides were viewed under a compound microscope at (x400 magnification). Fungal strains were thereafter identified based on the presence and characteristics of typical structures, such as conidia or spores, conidiophore, hyphae and phialide, and compared with standard reference descriptions of fungi (Barnett and Hunter, 2010).

Maize seed germination test

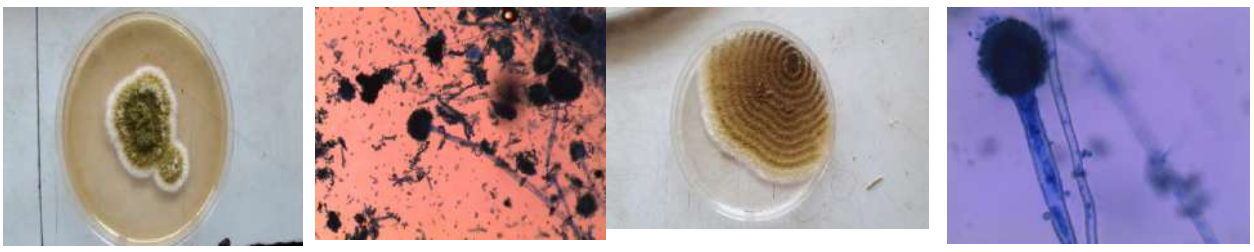
To determine the effect of soil contamination with lead on seed germination, maize seeds (Ife hybrid 3) were surface sterilised with 1% sodium hypochlorite for two minutes and subsequently washed (thrice) with sterile distilled water to eliminate the exogenous microbial contamination (Varpe, 2021). Seeds were blotted dry and arranged (10 seeds per plate) in amended lead contaminated soil samples. The experiment was laid out in a completely randomised design with three replicates. Petri plates were kept at room temperature (25±2°C) in the Laboratory and seeds were observed daily for germination. Percentage seed germination was recorded 10 days after planting. The seeds were considered to have germinated when a radicle length of 2 mm protrudes through the seed coat (Nciizah, *et al.,* 2020). Data were analysed (analysis of variance) using DSAASTAT, 2012 version and means were separated using the Least Significant Difference (LSD) at 95% level of probability.

RESULTS AND DISCUSSION

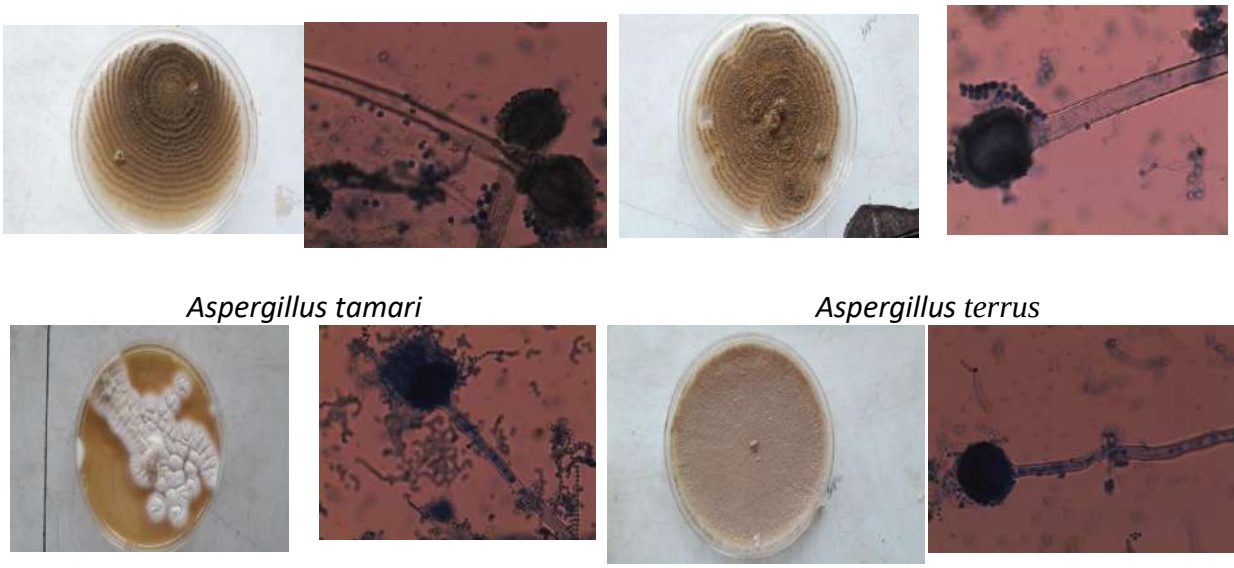
Effect of lead contamination on fungal load

Table 1 shows the effect of different concentration of lead on soil associated fungi. The heterotrophic fungal count in lead contaminated soil ranged from 3.2×10^3 to 0.00 CFU/mL. The lowest fungal count (0.00 CFU/mL) was observed in the unamended 100% Pb contaminated soil with 63.01 mg/kg Pb concentration, while 0% Pb contaminated soil with 0.36 mg/kg Pb concentration and amended with cow dung (30 t/ha) had the highest fungal count of 3.2×10^3 CFU/mL. Abundance of soil associated fungi declined with increase in lead concentration. Fungal count of 2.90×10^3 CFU/mL was recorded in lower level of lead contaminated soil (at 0.36 g/kg lead concentration) fertilized with compost; this was significantly higher than fungal abundance observed in other compost-fertilized contaminated soil samples. Control (uncontaminated sample with no fertilizer) soil had an abundance of 1.72×10^3 CFU/mL, this was however not significantly different from the abundance of fungi isolated from 21.55 g/kg lead contaminated soil fertilized with either 30 t/ha cow dung or compost.

Jan *et al.* (2020) investigated the dynamics of microbial communities in the soil, as well as their distribution and abundance in indigenous and artificially cultured microbial-based soil amendments, they reported an abundance of soil fungal population at a range of 2×10^4 to 8×10^4 CFU/g of prepared soil samples. The spectrum of fungal load generally varies in different soils. Concentrations on the surface of commercial soil, sub-surface potting soil, and compost range between 9.5 × 104 and 5.5 × 105 CFU/g (Haas *et al*., 2016). Di Piazza *et al*. (2020), in their report on the thermotolerant and thermophilic mycobiota in different steps of compost maturation, also attributed the complex biochemical processes resulting in the breakdown of organic matter to the presence and abundance of fungal species. The fungal load reduction observed in contaminated soil could be associated with the inhibitory effects of lead on the microbial community associated with each soil sample. High lead concentrations can disrupt several key metabolic processes or structures required for survival and growth, such as the electron transport chain, integrity of organelles, membrane stability index, metabolism of mineral nutrients, and cellular enzymatic activities (Aslam *et al.*, 2021). *Aspergillus fumigatus, A niger, A. flavus, A. nudulans, A. tamarii, A. uvarum and A. terreus* were the fungi species isolated from contaminated soil samples amended with organic fertilizers (Plate 1). Lead contamination could have adverse effects on the growth and proliferation of fungal species associated with the soil samples (Aslam *et al.*, 2021). This could negatively influence fungal diversity in contaminated soil, selecting for the growth of lead-resistant or Pb-metabolizing genera, such as *Aspergillus*. Toxic effects of lead contamination (resulting from the anthropogenic activities within the soil environment) on plants, animals, and microbial life forms were also reported by Sangeetha *et al.* (2021).



Aspergillus flavus *Aspergillus terrus*



Aspergillus tamari *Aspergillus terrus*

Aspergillus fumigatus *Aspergillus uvarum*

Plate 1: Culture plates and photomicrograph (x400) of *Aspergillus* species isolated from lead-contaminated soil

Influence of lead contamination on maize germination

Germination of maize seeds was significantly affected by lead concentration in the soil, percentage germination decreased with increment in the level of contamination (Table 1). Highest percentage germination (81.81) was observed in the control soil. However, this was not significantly different from the percentage germination on 0.36 g/kg lead contaminated soil, amended with cow dung (30 t/ha). Percentage germination recorded for other contaminated soil samples fertilized with cow dung were not significantly different. Of all the compost fertilized soil samples, soil with 63.01 g/kg Pb had the lowest germination percentage (0.00%), this was not significantly different from the germination rate recorded on 63.01 g/kg lead contaminated soil without organic amendment.

Table 1: The effects of soil amendments on germination of maize and abundance of soil fungi in Pb contaminated soil

Organic fertilizer application (30 t/ha)	Lead contamination (g/kg)	Fungal abundance ($\times 10^3$ CFU/mL)	Maize germination (%)
Cow dung	0.36	3.20±0.37^{a‡}	80.00±5.80^{a}
	9.38	2.00±0.12^{bc}	73.30±3.30^{ab}
	21.55	1.30±0.15^{d}	70.00±0.10^{ab}
	44.63	0.73±0.88^{ef}	60.00±10.01^{bc}
	63.01	0.27±0.89^{fgh}	0.00±0.00^{d}
Compost	0.36	2.90±0.30^{ab}	76.70±6.70^{ab}
	9.38	1.90±0.88^{c}	63.30±12.01^{bc}
	21.55	1.30±0.12^{d}	63.31±3.30^{bc}
	44.63	0.67±0.89^{efg}	56.7±6.70^{c}
	63.01	0.17±0.12^{gh}	0.00±0.00^{d}
NFA†	0.36	2.70±0.36^{b}	80.01±5.80^{a}
	9.38	0.87±0.67^{de}	60.00±15.31^{bc}
	21.55	0.23±0.66^{fgh}	66.7±3.30^{bc}
	44.63	0.13±0.33^{h}	66.7±3.31^{bc}
	63.01	0.00±0.00^{h}	0.00±0.00^{d}
Control	0.00	1.72±0.44^{cd}	81.81±5.04^{a}

† NFA: No fertilizer application.

‡ Means followed by the same letter(s) within a column are not significantly different at 5% probability level according to Least Significant Difference (LSD) test.

A very high concentration of lead was observed in the contaminated soil sample used in this study. Soil contamination with lead due to anthropogenic activities has significantly increased in recent time; therefore, remediation is of prime importance due to its recalcitrant properties and toxicity effects (Sangeetha *et al.,* 2021). Several techniques have been proposed towards heavy metal remediation, however, bioremediation is considered the safest, readily available and affordable group of methods to reduce the toxicity effects of heavy metal contamination (da Silva *et al*., 2020). Cow dung and compost improved the soil microbial properties and their ability to support the emergence of maize. Organic matter contents have been described to possess high variability of structures, diverse microbial communities, and chemical functional groups with bioremediation potentials (Coutinho *et al.,* 2021). Organic fertilizer application in this study appeared to have reduced the toxicity of lead to maize seeds in the contaminated soil samples. In addition to the possibility of adsorbing heavy metal contaminants, da Silva *et al*. (2020) also reported manure application as a means of augmenting the microbial complexity of different soil types. Organisms associated with manure include plant growth-promoting microbes, as well as several organisms associated with heavy metal bioremediation.

The use of plant growth-promoting microorganisms has been proposed as an inexpensive strategy for remediating lead contaminated soils. Aslam *et al*. (2021)

reported the use of Ascomycetes for successful bioremediation, especially, in cereal crops. The fungi were observed to establish a symbiotic relationship with host cereal, improving lead-tolerance by immobilising Pb ions. *Aspergillus* species isolated from lead contaminated soil samples could also be associated with lead bioremediation. Bala *et al.* (2020), in their study on biosorption potentials of lead tolerant fungi, also reported *Aspergillus* species with lead removal capacities of 0.67 ppm, 3.11 ppm and 3.79 ppm in lead-contaminated sterile, Saboraud Dextrose Broth. According to this report, organisms involved in plant's resistance to heavy metals are capable of influencing transcription factors, metal tolerance protein (MTP), natural resistance-associated macrophage protein (NRAMP), and heavy metal ATPase. Sangeetha *et al.* (2021) also reported the production of biosurfactants by soil associated microorganisms, which are capable of adsorbing between 96%–99.6% of lead in contaminated soil, using the Langmuir isotherm model assay.

CONCLUSION

Cow dung and compost (*Tithonia rotundifolia* and poultry droppings) were used as soil amendments in lead contaminated soil samples. These organic fertilizers reduced lead toxicity on maize seeds, thereby improving their percentage germination. However, microbial abundance and the rate of maize germination decreased with increase in lead concentration. Lead contamination also appeared to have inhibited the growth of soil-associated fungi, reduced their diversity and possibly accounted for the proliferation of *Aspergillus* species isolated in this study. Cow dung had better effect (than compost) in mitigating lead toxicity on soil fungi and maize seeds. Organic fertilizers are cheap, easily accessible agricultural waste, which could be considered in the development of efficient lead bioremediation strategies, especially, in the production of maize. In addition to their potentials to reduce the sensitivity of maize to heavy metal contamination, these manures could simultaneously serve as sources of essential nutrients required for crop production.

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AGRO-ECOLOGICAL TECHNIQUES FOR SUSTAINABLE POULTRY PRODUCTION: EVIDENCE FROM HAEMATOLOGICAL PARAMETERS

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ABSTRACT

For the purpose of sustainable utilization of ecological resources in mitigating climate and other challenges, agro-ecological techniques were investigated for poultry production. This report is focusing on an aspect of the research. One hundred and fifty-three local birds: 51 each of ducks, guinea fowls and chickens were mixed reared semi-intensively in triplicates of 17 birds per species per pen. Every pen has indoor and outdoor settings. Plants were planted in the outdoor as supplementary feeds while at the indoor they were fed with compounded feed. The experiment was conducted for 16 weeks after which blood samples were collected from two birds per species per pen and were analysed for haematological parameters. The range of values obtained were PVC (28.3-39%); HB (9.7-12.4g/dl) ; WBC (26.7-33.7x10^3cells/ml); RBC (2.47-3.5x10^6 cells/ml); MCHC (31.8-32.7g/dl); MCH (26.7-55.1pg); Hct (28.3-29%); MCV (83.8-173.1FL). As evident from the haematological parameters of the local birds, the agro-ecological techniques of semi-intensive system with supplementary plants and compounded feeds have no detrimental effects on the wellbeing (health) of the local birds which in turn to the human consumers while local ducks and guinea fowls showed potential competitiveness with broilers. Therefore, the techniques are hereby recommended, however, subsequent reports from the research will focus on other aspects of reproductive indices such the growth performance and economic cost-benefit analysis for a comprehensive and holistic recommendations.

Key words: Mixed species rearing, semi-intensive system, supplementary plant feed, haematological Parameters

INTRODUCTION

Sustainability of utilization of resource for the benefit of man is a strong pillar of Sustainable Development Goals. Man is essentially being product of his environment can better sustain utilizing his resources as long as the provision is within his local and immediate environment. Kumar *et al.* (2021) identified three issues which society is faced with from the perspective of studying life cycle assessment (LCA) and sustainability analysis; these issues are population growth, climate change and depletion of resources. Actually, optimal utilization of resources can tackle challenges associated with population growth and climate change. While resource depletion is an illusion as laws of conservation of energy is applicable to resources in the sense that resources are neither created nor destroyed but are transformed through spatio-temporal dynamics for instance human excreta that used to be easily deposited into the soil and decompose to release its nutrients are cumulatively trapped in suck-away in the cities, hitherto, leading to depletion in soil fertility and of course depleting agricultural resource and productivity. Similarly the rural-urban migration reduced the potential impact of population on

utilization of natural resources, thereby, rendering more unproductive or with strain on secondary/ artificial resources.

However, in this 21st century, LCA serves as a strong tool that has been used to checkmate potential environmental problems for the whole life cycle of a product. Sustainable food production gains priority globally (Loboguerrero *et al.*, 2019). Sustainability is considered as a development that meets the present demands without compromising the ability for the future generation to meet their own needs (Mensah, 2019) and managing the food system and agriculture is crucial, especially when meeting future generation's growing needs. Sustainability involves environmental responsibility; social awareness; and economic profitability.

Poultry production is an essential component of the global food supply, providing a major source of animal protein, vitamins, and minerals, making them an important part of a healthy and nutritious diet around the world (Marangoni *et al.*, 2015). However, the common practice in poultry production is single species rearing and mostly exotic breeds in an intensive system while this research seeks to investigate mixed species rearing and of local breeds using semi-intensive system with compounded and supplementary plant feeds for meat production. This specific report is focused on results of comparing their blood parameters to observe if it is within normal ranges.

MATERIALS AND METHODS

Study Area

The experiment was carried out at the Research and Teaching Farm of Abubakar Tafawa Balewa University, Yelwa Campus, Bauchi, Bauchi State, Nigeria. The experiment was conducted for a period of 16 weeks.

Experimental Design

The mixed reared local birds were duck, guinea fowl and chicken. Seventeen of each species making a total of 51 per pen and was replicated thrice in three pens. Each pen has both indoor and outdoor facilities simulating the semi-intensive system with the outdoor caged with net to prevent the guinea fowls from flying away. Within the indoor birds were fed with supplementary compounded feed. Started supplement for the first eight (8) weeks and grower supplement for the last eight (8) weeks; the percentage compositions of the supplements and their proximate analysis were as in Tables 1 and 2 respectively.

Plants were planted in the outdoor space for the mixed reared birds to feed on as plants supplementary feeds. The major plants were *Moringa Oleifera* (Moringa) where the birds fed on the leaves and *Cymbopogon citratus* (Lemon grass). The proximate compositions of the plants were as elucidated in Table 3. Water is constantly provided.

Blood Sample Collection for Haematological Parameters

Samples of blood were taken from two birds per species per replicate at the end of the 16 weeks. The blood samples for haematological parameter were collected into tubes containing EDTA (Ethylenediaminetetraacetic acid) as anti-coagulant. Some parameters like the RBC, WBC PVC were analysed at the laboratory while others were calculated.

RESULTS AND DISCUSSION

The starter supplement had calculated Crude Protein and Metabolisable Energy of 19.2% and 2750 respectively while the grower supplement had calculated values of 15.53 and 2610 of Crude Protein and Metabolisable Energy respectively (Table 1). However, the analysed proximate composition of the starter and grower supplements were Dry Matter (%): 96.08 and 95.45 Crude Fibre (%): 5.50 and 7.80; Lipid/Ether Extract (%): 3.25 and 3.77 and Ash (%): 4.00 and 4.56 respectively as elucidated in Table 2.

Table 1: Percentage Composition of Supplementary Compounded Diets

Ingredients	Starter Supplement (%)	Grower Supplement (%)
Maize	48.0	45.0
GNC	27.0	20.0
Maize Offal	15.5	25.5
Rice Offal	5.0	5.0
Bone Meal	3.5	3.5
Salt	0.3	0.3
Premix	0.2	0.2
Lysine	0.2	0.2
Methionine	0.3	0.3
Calculated Analysis:		
Crude Protein	19.2	15.53
Metabolisable Energy	2750	2610

Table 2: Proximate Composition of Compounded Supplementary Feeds

Parameters	Supplementary Feed	
	Starter	Grower
Crude Protein	19.20	15.53
Dry Matter	96.08	95.45
Crude Fibre	5.50	7.80
Lipid (Ether Extract)	3.25	3.77
Ash	4.00	4.56
Calcium	1.22	1.50
Phosphorus	0.48	0.77
Metabolisable Energy	2750.00	2610.00

Crude Protein (28.00%) of *Moringa Oleifera* Leaf was higher than even the starter compounded feed (19.20%) while its Metabolisable energy (2625.25%) compared reasonably with the grower supplement (2610.00%) as shown in Table 3. This could be one of the reasons why some local chickens raised in the rural areas or in suburban settlements could thrive by feeding on plants without commercial or compounded feeds. Such plants could be rich in nutrients to meet up with the nutritional requirements of the chickens.

There were other plants that were planted outdoor the three pens prior to commencement of the experiment but of all only moringa and lemon grass were resilient that survive and support the mixed reared species from natural rain fall throughout the experimental period and even survive beyond the period in the pens.

Table 3: Proximate Composition of Supplementary Plant Feeds

Parameters	*Moringa Oleifera* Leaf (%)	*Cymbopogon citratus* (%)
Crude Protein	28.00	15.56
Moisture	7.88	5.76
Dry Matter	92.12	94.24
Lipid (Ether Extract)	3.88	5.10
Ash	9.82	20.0
Crude Fibre	12.57	9.12
Nitrogen Free Extract	37.87	55.00
Metabolisable Energy	2625.25	2450.00

Table 4: Haematological Parameters of the mixed reared Local Birds

Parameter	Duck	Guinea Fowl	Chicken
PVC (%)	39	34.7	28.3
HB (g/dl)	12.4	11.0	9.7
WBC (10^3cells/ml)	26.7	32.8	33.7
RBC (10^6 cells/ml)	2.47	2.97	3.5
MCHC (g/dl)	31.9	31.8	32.7
MCH (pg)	55.1	45.7	26.7
Hct (%)	39	34.7	28.3
MCV (FL)	173.1	143.9	83.8

PCV= packed cells volume, Hb= Haemoglobin, mean corpuscular volume, MCHC= Mean corpuscular Haemoglobin concentration MCH=Mean corpuscular Haemoglobin.

Packed cell volume (PCV) ranged from 28.9 – 39%. The upper range value is higher than range of 29.83-33.15% that was reported by Nwafor *et al.* (2023). The values were also higher than range of values of 20.00 – 31.67% reported by Medugu *et al.*. (2010). The duck and guinea fowl values of 39% and 34.7% respectively were lower than the ranges of values of 32.15 – 39.88% reported for exotic chickens by Lakurbe *et al.*. (2020). The PCV gotten from this study were within the normal range of 25.00-45.00% as reported by Opoola *et al.* (2013) indicating that the birds were well nourished not anaemic. Although, haemoglobin count obtained in this study for local chicken (9.7g/dl) was lower than haemoglobin values range 9.93 -10.78g/dl reported by Nwafor *et al.* (2023); however, the values of local duck (12.4g/dl) and guinea fowl (11.0g/dl) obtained in this study were higher than those reported by Nwafor *et al.*. (2023). These values were far higher than 4.07 – 6.83g/dl reported by Medugu *et al.* (2010) and 10.20 – 10.90g/dl as reported by Lakurbe *et al.*. (2020) as well as the values of Haemoglobin (9.90 - 11.50g/dl) obtained by Onabanjo *et al.* (2021). Haemoglobin values obtained from this study are within the normal range of 7.00 – 13g/dl for Haemoglobin concentration in broiler chickens as reported by Opoola *et al.* (2013) indicating that the production techniques used in this study are have no detrimental effect on the local birds that were mixed reared with the supplementary compounded feed and plants. Mean corpuscular volume (MCV) for local chicken (83.8FL) was very low compared range reported by Nwafor *et al.* (2023): 141.32-148-98FL but MCV of local duck (173.1fFL) and local guinea fowl (143.9FL) were higher than the range reported. These values are also higher than 97.13-119.20FL reported by Medugu *et al.* (2010) and 148.55-159.75FL obtained by Lakurbe *et al.* (2020). While of course local chickens reported in this study are lower in haematological parameters compared to other reports but local ducks and guinea fowls are showing higher values than those reported for broilers in other researches. Mean corpuscular Haemoglobin concentration (MCHC) values range from 31.8 – 32.7 were lower than the range reported by Nwafor *et al.* (2023) from 40.08 – 137.05 but were slightly higher than the values reported by Lakurbe *et al.* (2020) who obtained 29.70 – 31.75g/dl. A high MCHC above the normal range may be an indication of anaemia-Autoimmune haemolytic anaemia or dehydration (Lynne 2022) but the RBC and WBC values were very good indicators that the local birds were not anaemic and has active immune response. Similarly MCH range of values obtained in this study from 26.7 – 55.1pg were lower in range than 63.73 – 67.78pg reported by Nwafor *et al.* (2023) while higher than range of values of 18.06 – 22.76pg reported by Medugu *et al.*. (2010) and 46.25 – 48.30pg as reported by Lakurbe *et al.* (2020).

CONCLUSION AND RECOMMENDATION

As evident from the haematological parameters obtained of the local birds in this research report, the agro-ecological techniques of semi-intensive system with supplementary plants and compounded feeds have no detrimental effects on the wellbeing (health) of the local birds which in turn to the human consumers while local ducks and guinea fowls showed potential competitiveness with broilers. Therefore, the techniques are hereby recommended, however, subsequent reports from of the research will focus on other aspects of reproductive indices such the growth performance and economic cost-benefit analysis for a comprehensive and holistic recommendations.

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SEDIMENTOLOGICAL, BIOSTRATIGRAPHIC AND WIRELINE LOG ANALYSIS OF ELE-1 WELL, NIGER DELTA BASIN, NIGERIA

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ABSTRACT

ELE-1 Oil Well samples were subjected to sedimentological, biostratigrapic and Wireline log analyses for well-based characterisation. One hundred (100) ditch cutting samples were analysed for sedimentological characteristics and a lithologic section was produced based on the results of the analysis. ELE-1 Well ranged from 160ft (48.77m) to 12580ft (3,834.38m) with a total thickness of 12420 ft (3,785.62m) ranging from depths of 160 ft – 12580 ft. The lithologic section showed that it was mainly sandstone from 160 ft to 8380 ft (2,554.22). Shale was encountered at 8380 ft and alternated with sandstone till 9920 ft. A thick section of shale was displayed from 9920ft to 12580 ft. The well had four (4) Maximum Flooding Surfaces (MFSs) and three Sequence Boundaries (SBs). They were picked and dated as P870/P830 (5.0Ma MFS), P870/P830 (5.6Ma SB), P870/P830 (6.0 Ma MFS), P870/P830 (6.7Ma SB), P830/P870 (7.4Ma MFS), P820/P788 (8.5Ma SB), P820/P788 (9.5Ma MFS). The sequence stratigraphic surfaces enable the Third (3rd) order sequence stratigraphic characterization, which can achieve a detailed reservoir prediction

Keywords: Sedimentological, Biostratigraphic, Wireline Log, Characterisation, Sequence Stratigraphy

INTRODUCTION

Positioned in the eastern Gulf of Guinea, the Niger Delta Basin is one of the world's most abundant petroleum basins. The Niger Delta is located in Nigeria's South-South geopolitical zone, between latitudes 4°N and 7°N and longitudes 3°E and 9°E. The Cenozic Niger Delta is located where the South Atlantic Ocean and the Benue Trough meet, a triple junction formed in the late Jurassic period when the African and South American plates separated (Obaje, 2009). One of the sedimentary basins created by the rift faulting of Nigeria's Precambrian rock is the Niger Delta Basin. The delta is made up of pieces of the extended African continental crust and Tertiary marine and fluvial deposits that lie on top of oceanic crust (Bilotti and Shaw, 2005).

Since commercial oil was discovered in the Oloibiri-1 well in 1956, the Niger Delta has been a significant hydrocarbon producing area in Nigeria, the focus of intense exploration and exploitation activity since the early 1960s (Reijers *et al.*, 1996). Thus, to explore and utilise the hydrocarbon resources of the delta, one must have a thorough grasp of its lithostratigraphy, biostratigraphy, sedimentology, and palaeoenvironment.

Geological Setting

Study Area

The study well "ELE-1 Well" is located in the Coastal Swamp Depobelt of the Niger Delta Basin (Figure 1)

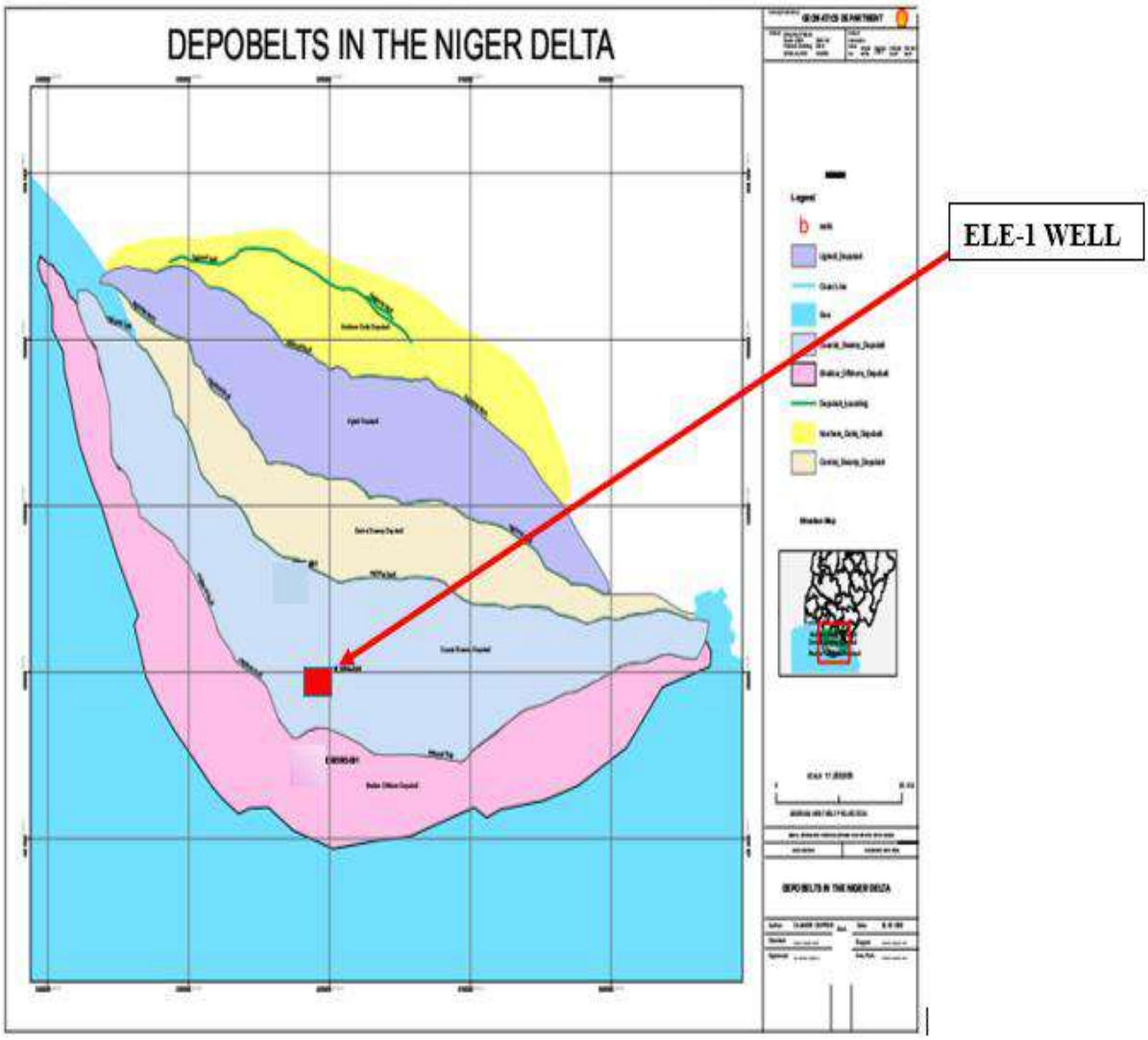

Fig 1: Location of Study Area – Coastal Swamp Depobelt - (in red) insert in the Regional Niger Depobelts. (Modified from SPDC Creations 2008)

Regional Niger Delta Development.

The Niger Delta Basin is located on the continental margin of the Gulf of Guinea in equatorial West Africa (Figure 2). The Delta originated at the location of a triple junction of rifts connected to the Southern Atlantic opening, which occurred between the Late Jurassic and Early Cretaceous periods. In the Eocene, the Delta proper started to form and fill with sediment. Beginning in the Eocene, the Delta proceeded southwestward, creating depobelts, which symbolised the most dynamic areas of the Delta throughout its evolution (Doust and Omatsola, 1990). The Niger Delta Basin may be further classified into three formations (Figure 3): The Agbada Formation (Eocene to Recent), the Benin Formation (Oligocene- Recent), and the Pro-delta shales of the Akata Formation (Palaeocene to Recent). It is a sizable, constructive wave-dominated delta with an arcuate sediment wedge in cross-section.

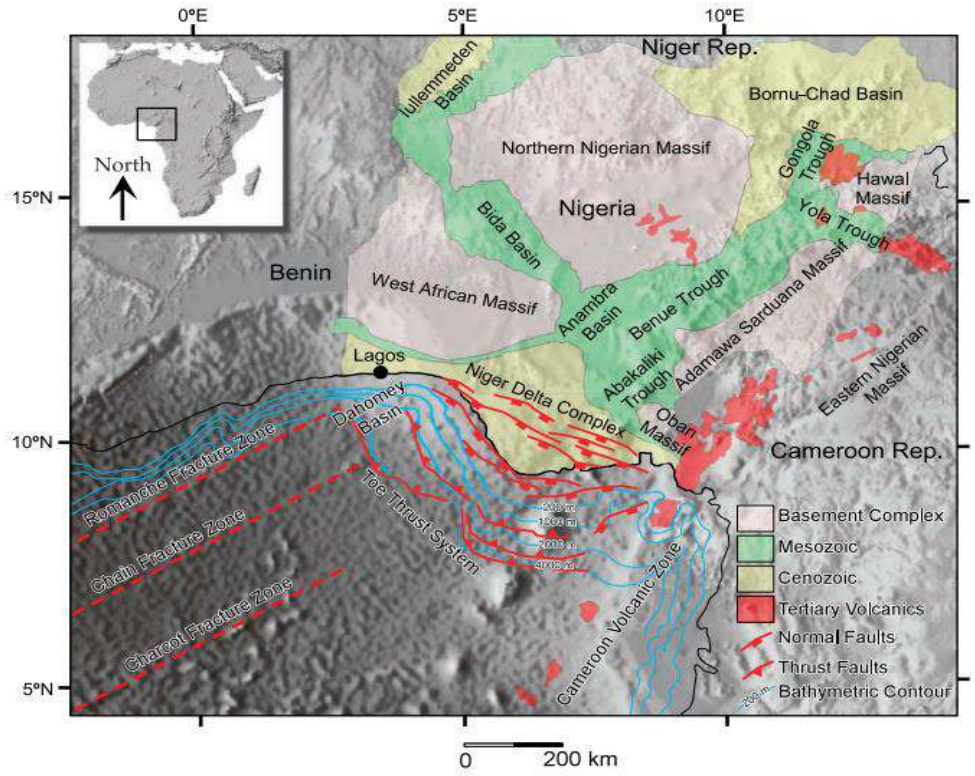

Figure 2: Location of the Niger Delta region showing the main sedimentary basins and tectonic features. The delta is bounded by the Cameroon volcanic zone, the Dahomey Basin, and the 4,000-m (13,100-ft) bathymetric contour (After Onuoha,1999).

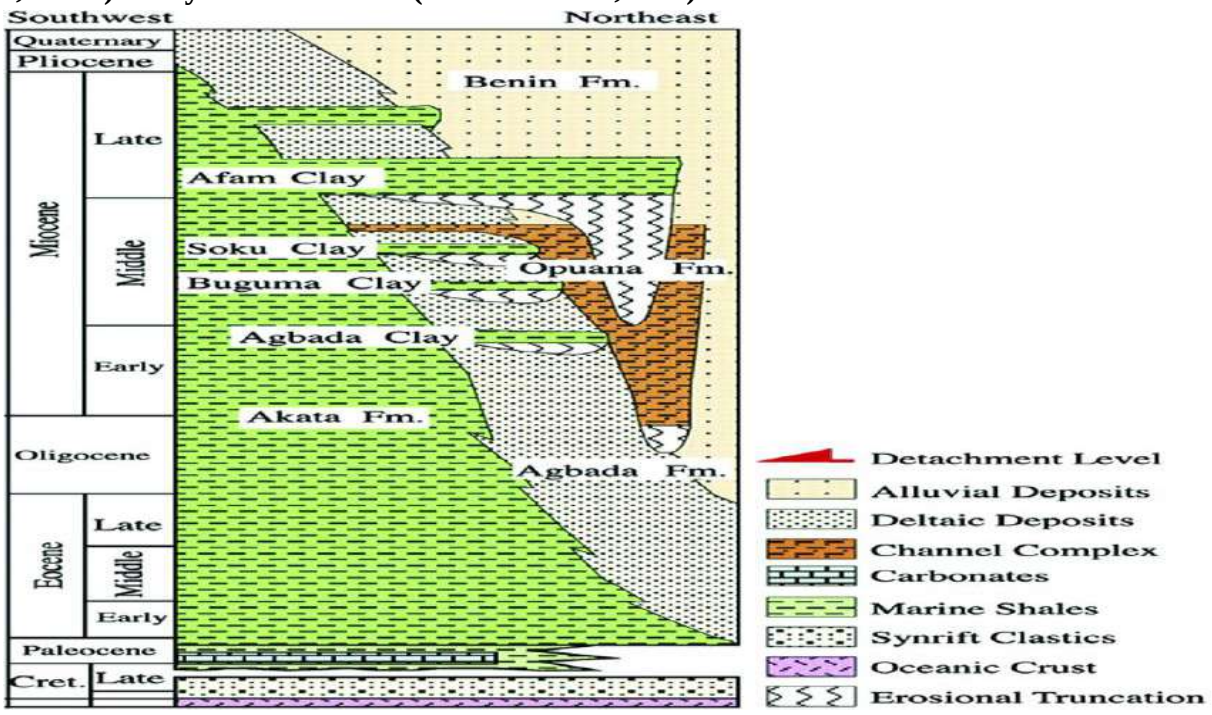

Figure 3: Stratigraphic column showing the 3 formations of the Niger Delta (Doust and Omatsola. 1990)

The Akata Formation was deposited in the Paleocene. The primary constituents of the Akata Formation, the base unit of the Cenozoic delta complex, are marine shales (a probable source rock), turbidite sands (a possible reservoir in deep water), and trace quantities of silts and clay (Figure 2). Sediments are formed because the high energy delta progressed into deep water; the approximate range of thickness is 0-6000 metres (Fatoke *et al.*, 2010), (Schlumberger, 1985). Because of its constant shale growth, the shale is often dark grey, although it can also be silty or sandy in certain areas and include thin sandstone lenses, particularly in the upper section of the formation (Short and Stauble, 1967). This Formation originated during lowstands, when clays and terrestrial organic materials were carried to deep water regions with low oxygen levels and energy levels (Michele *et al.*, 1990).

The Agbada Formation was deposited in the Eocene. Shale diapirs were created as a result, pressing the underlying shale (Akata Formation) onto them. According to Nwachukwu and Odjegba (2001), the Agbada Formation (Figure 2) is a paralic sequence of alternating sandstones and shales deposited on a shoreline's landward side. The sandstone reservoirs of the Agbada Formation are responsible for the Niger Delta's oil and gas production. The formation is made up of an alternating series of delta-front sandstones and shales, with a paralic siliciclastic origin that is over 3700 metres thick and originates in a distributary channel and deltaic plain. The sandstones have fine grains, are clear, calcareous, glauconitic, and occasionally shelly. The silty shales have a medium to dark grey colour and include local glauconite. It is composed of a lower shale level that is thicker than the upper than the upper sandy unit and an upper mostly sandy unit with small shale intercalations.

A higher rate of deposition in the delta front is indicated by the formation's dense microfauna near the base, which decreases upward. The coarse grains and poor sorting are signs of a fluviatile origin. This series is associated with sedimentary growth faulting and contains hydrocarbon reserves. The top rock is composed of shale beds, whereas the main hydrocarbon deposits are found in the sand layers.

The Benin Formation was then created throughout the Oligocene and continues to be deposited now. The Benin Formation (Figure 2) extends southward past the present seashore and across the Niger Delta from west to east. It is mostly composed of massive, very porous, freshwater-bearing sandstones with thin, shale-like interbeds that are assumed to have originated from braided streams. In terms of minerals, the sandstones are mostly composed of quartz and potash feldspar, with trace quantities of plagioclase. With shale intercalations, more than 90% of it is sandstone. It has a range of grain sizes, from coarse to fine, is gravelly in some areas, is poorly sorted, sub-angular to well-rounded, and has pieces of wood and lignite streaks throughout. Because to its tectonic structure, the basin is divided into a few distinct zones. Because of the thicker crust, the ocean floor has an extensional zone. Within the deepwater portion of the basin, there are two zones: one for transition and the other for contraction. (Fatoke and others, 2010).

The geology of southern Nigeria and southwest Cameroon defines the onshore area of the Niger Delta Province. Stable mega-tectonic frameworks flank the Niger Delta Basin. These include the Calabar and Benin flanks along the delta's eastern and northwest borders, respectively. The delta's northern limit is indicated by the Anambra Basin and Abakaliki. The Niger Delta Basin is bordered to the south by the Gulf of Guinea. Situated between latitudes 4^{o} and 7^{o}N and longitudes 3^{o} and 9^{o}E, it is the oil province of Nigeria (Whiteman, 1982).

The whole sedimentary prism, spanning 140,000 km^3 (75,000 km^3), is made up of an overall regressive clastic sequence that reaches a maximum thickness of 9,000–12,000 metres. Its

stratigraphic thickness is approximately 12 km (Evamy *et al.*, 1978).

MATERIALS AND METHODS

This research involves different disciplines will be integrated to better highlight the final result. The study involves three phases of analysis viz: sedimentological analysis, biostratigraphic data interpretation and Wireline Log analysis.

Materials used are:

Table 1: ELE-1 Well Sample Inventory

S/N	DEPTH	S/N	DEPTH	S/N	DEPTH	S/N	DEPTH	S/N	DEPTH
1	160	**21**	2660	**41**	5160	**61**	7660	**81**	10160
2	280	**22**	2780	**42**	5280	**62**	7780	**82**	10280
3	400	**23**	2920	**43**	5400	**63**	7900	**83**	10400
4	520	**24**	3020	**44**	5520	**64**	8020	**84**	10520
5	640	**25**	3140	**45**	5640	**65**	8140	**85**	10640
6	760	**26**	3260	**46**	5760	**66**	8260	**86**	10760
7	880	**27**	3350	**47**	5880	**67**	8380	**87**	10880
8	1000	**28**	3500	**48**	6000	**68**	8500	**88**	11000
9	1120	**29**	3620	**49**	6120	**69**	8620	**89**	11120
10	1240	**30**	3740	**50**	6240	**70**	8740	**90**	11240
11	1360	**31**	3860	**51**	6360	**71**	8860	**91**	11360
12	1480	**32**	3980	**52**	6480	**72**	8980	**92**	11480
13	1600	**33**	4100	**53**	6600	**73**	9100	**93**	11600
14	1720	**34**	4220	**54**	6720	**74**	9220	**94**	11720
15	1840	**35**	4340	**55**	6840	**75**	9340	**95**	11840
16	1940	**36**	4500	**56**	6980	**76**	9480	**96**	11980
17	2100	**37**	4620	**57**	7120	**77**	9620	**97**	12120
18	2240	**38**	4760	**58**	7260	**78**	9760	**98**	12260
19	2380	**39**	4900	**59**	7400	**79**	9900	**99**	12380
20	2540	**40**	5040	**60**	7540	**80**	10040	**100**	12580

- Well Ditch Cutting samples
- Well Wireline Log
- Biostratigraphic data (F-zones, P-zones and abundance array of both forams and palynological data)
- Niger Delta Cenozoic Chart

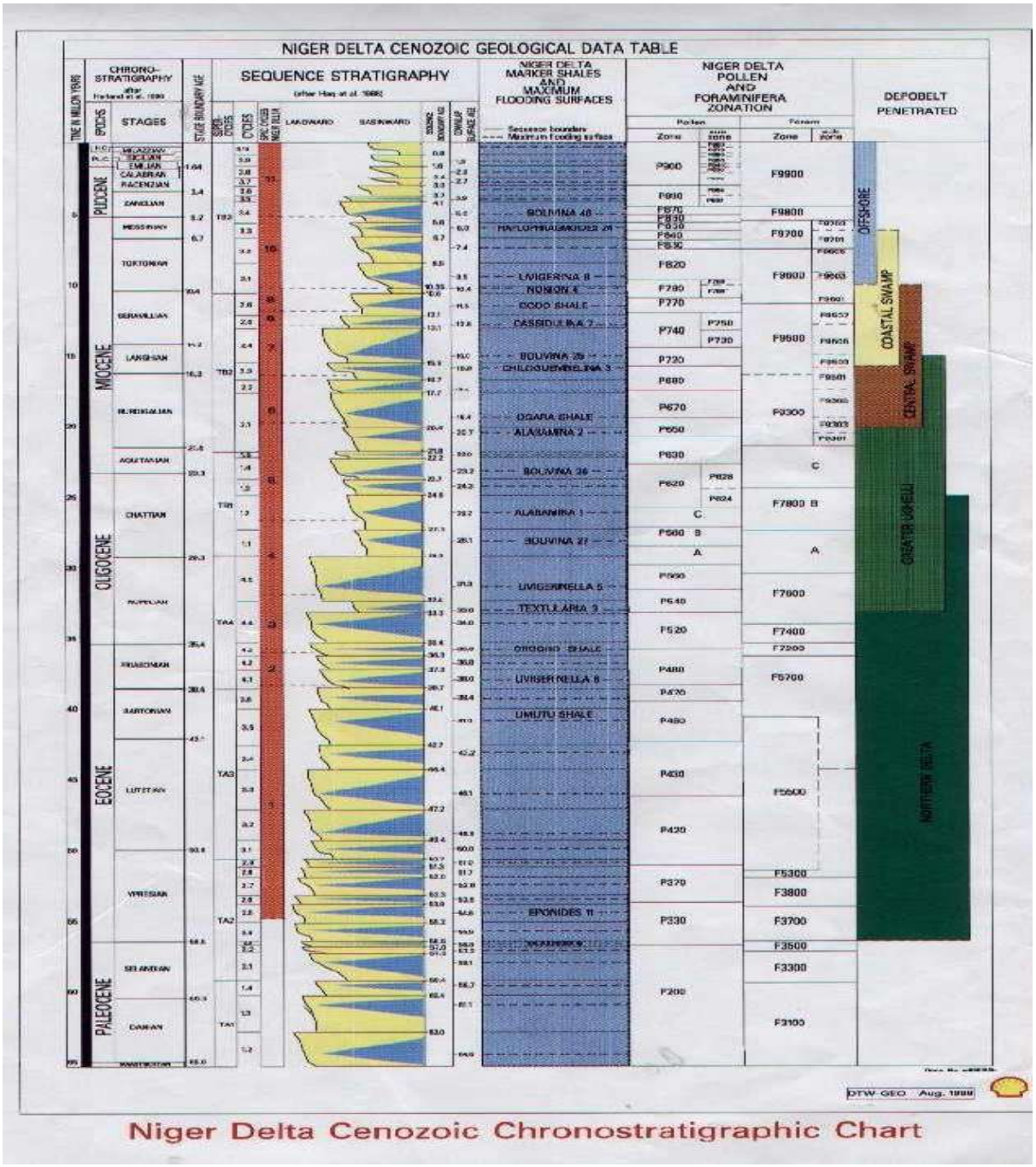

Figure 3: The SPDC Niger Delta Cenozoic Chronostratigraphic Chart (SPDC, 1988)

Methods used are:

a. Sedimentological Analysis

The sedimentological analysis of the well samples involved washing the samples initially with water to remove the contamination of the drilling mud, since the drilling mud used is water based mud. After that, the washed samples were dried in pans placed on hot plates. After the drying, the samples were viewed and analyzed with the aid of a microscope for

sedimentological description of the samples with particular focus on sediment texture, sorting and lithologic type

b. Wireline Log Analysis

The Wireline logs used were the Caliper Log, Gamma Ray Log and the Spontaneous Potential (SP) Log. These logs are sensitive to sediment variance and therefore can delineate between sand and shale lithologies

c. Biostratigraphic Interpretation

Biostratigraphy is a powerful tool for constraining the ages of stratigraphic sequences. When integrated with wireline logs, it becomes very useful to locate sequence boundaries (SB) and condensed sections Maximum Flooding Surface (MFS).

RESULTS

Sedimentological Analysis

The sedimentological analysis of ELE–1 Well was carried out using one hundred (100)) ditch cutting samples (Table 1) and samples description was done with the production of a resultant lithologic section (Table 2).

Table 2: Sedimentary Description of ELE-1 (Coastal Swamp Depobelt) Well Samples

SEDIMENTARY DESCRIPTION OF ELE-1 (COASTAL SWAMP DEPOBELT) WELL SAMPLES WITH A LITHOLOGIC SECTION

1		*Coarse sand stone*					***DTH***	*DEPTH*		
2		*Medium/fine sand stone*					***SST***	*SAND STONE*		
3		*Very fine sand stone*					***SHL***	*SHALE*		
4		*Shaly sand stone*					***SLTS***	*SILT STONE*		
5		*Heterolic lithology*					***LITH***	*LITHOLOGY*		
6		*Sandy Shale*								
7		*Shale*								
S/N	***DTH***	***%SST***	***%SHL***	***%SLTS***	***LITHOLOGIC DESCRIPTION***				***ACCESSORY MINERALS***	***LITH***
1	*160*	*50*	*50*	*0*	*Heterolic, light gray, very fine, well sorted, angular*					
2	*280*	*99*	*<1*	*<1*	*Sandstone, whitish, fine-coarse, poorly sorted,*				*Siderite*	
3	*400*	*99*	*<1*	*<1*	*Sandstone, whitish, coarse, moderately sorted,*				*Siderite*	
4	*520*	*98*	*1*	*1*	*Sandstone, whitish, fine-medium, well sorted,*				*Carbon*	
5	*640*	*99*	*<1*	*<1*	*Sandstone, colourless, medium, well sorted,*					
6	*760*	*100*	*0*	*0*	*Sandstone, whitish, medium, well sorted,*					
7	*880*	*100*	*0*	*0*	*Sandstone, whitish, medium, well sorted,*					
8	*1000*	*100*	*0*	*0*	*Sandstone, whitish, coarse, moderately sorted,*					
9	*1120*	*99*	*<1*	*0*	*Sandstone, whitish, fine, well sorted, angular*					
10	*1240*	*99*	*<1*	*<1*	*Sandstone, whitish, fine, well sorted, angular*					
11	*1360*	*99*	*<1*	*<1*	*Sandstone, colourless, fine, moderately sorted,*				*Siderite*	
12	*1480*	*99*	*0*	*1*	*Sandstone, brownish, fine, moderately sorted,*					
13	*1600*	*99*	*0*	*<1*	*Sandstone, colourless, medium, well sorted,*					
14	*1720*	*99*	*<1*	*<1*	*Sandstone, colourless, medium, well sorted,*				*Micaceous*	
15	*1840*	*100*	*0*	*0*	*Sandstone, whitish, fine, moderately sorted,*				*Carbon*	
16	*1940*	*99*	*<1*	*<1*	*Sandstone, whitish, fine-coarse, poorly sorted,*				*Ferruginized*	

ELE-1 Well samples displayed a lithologic section that is generally sandy at the top and the basal parts having intercalations of sand and shale lithologies. The sands range from very fine to coarse grained. The overall lithologic section suggests a lateral shifts of depositional environment from shallow to deep water environment (Lucas and Omodolor, 2018)

Biostratigraphic and Wireline Interpretations

A broad biostratigraphic framework was developed for the well with the MFSs determined based on biofacies abundance data with the associated sequences boundaries mapped. Wireline logs were used in conjunction with the biofacies data. Using an already established data of MFSs and SBs in the Niger Delta Basin as Portrayed in the Niger Delta Cenozoic Geological Data Chart (Fig. 3), the relative F and P zones and biofacies data of ELE-1 Well enabled the delineation of the MFSs and SBs in the well.

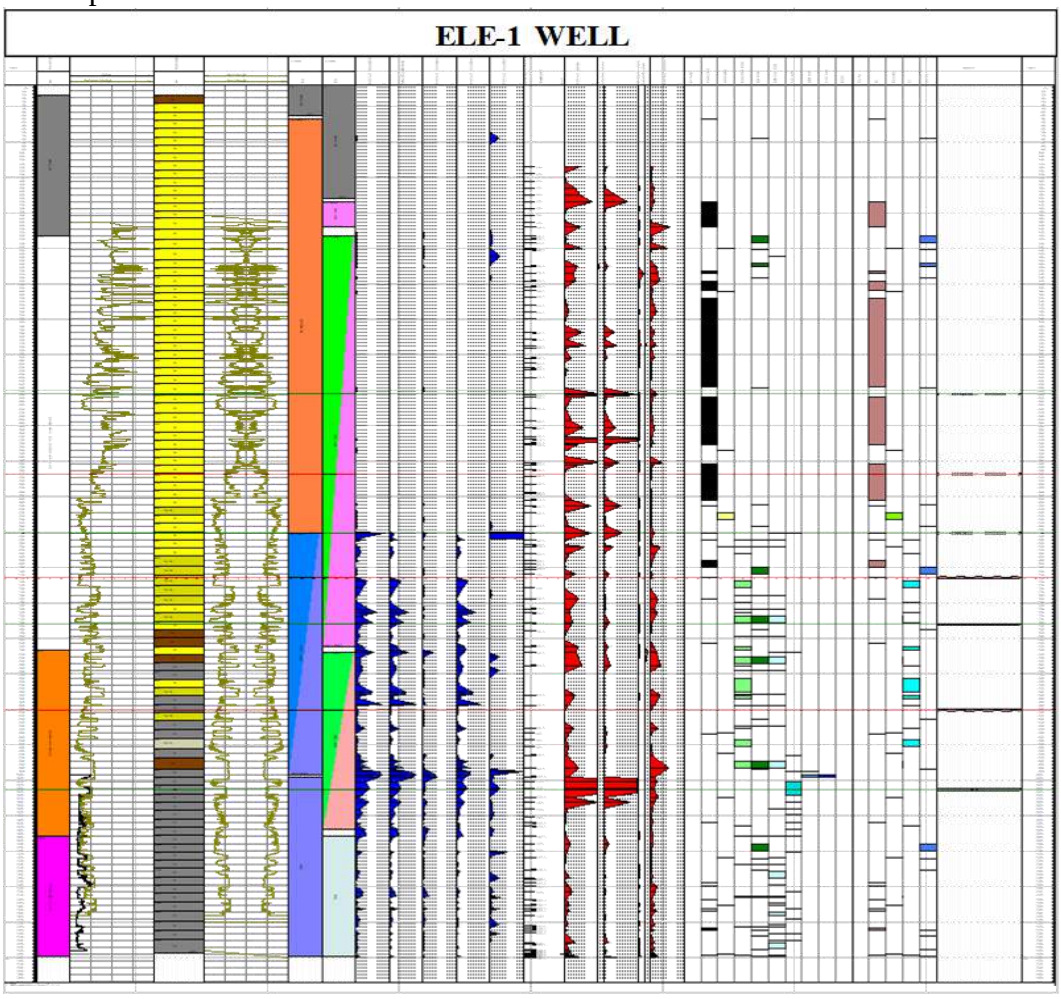

Figure 4: Stratabugs plot of ELE-1 Well composite interpretations. Showing the depth scale, wireline logs, interpreted lithologic section, F & P zones, biofacies abundance data and the stratigraphic surfaces (MFS & SB)

A broad biostratigraphic framework was developed for the ELE-1 Well with the MFSs determined based on biofacies abundance data with the associated sequence boundaries

mapped. Wireline logs were used in conjunction with the biofacies data.

Using an already established data of Maximum Flooding Surfaces (MFSs) and Sequence Boundaries (SBs) in the Niger Delta as portrayed in the Niger Delta Cenozoic Chart, the relative F- and P- zones and biofacies data of ELE-1 Well resulted to the delineation of the MFSs and SBs in the well (Fig. 4).

The biofacies data for ELE-1 and the Spontaneous Potential (SP) log were imported into the StraraBugs software. Matching the biofacies data and wireline signatures against the Niger Delta Cenozoic Chronostratigraphic Chart, MFSs and SBs were determined.

The first MFS was picked at the depth of 4490ft. It was tied to the abundance peak of palynology data and substantiated by a landward deflection of the SP log. The MFS is attributed to the Bolivina 46 event at 5.0Ma. It occurs within the undifferentiated P870/P830 biozones.

The first SB was determined at depth of 5650ft based on absence of biofacies data, landward deflection of the SP log and matching it with the 5.6Ma SB of the Niger Delta Cenozoic chart. It also occurs within the undifferentiated P870/P830 biozones.

At the depth of 6500ft, the second MFS was picked based on the abundance peaks of both the foram and paly data. It was picked again within the P870/P830 biozones. The MFS was tied to the 6.0Ma Haplophragmoides 24 event of the Niger Delta Cenozoic Chart.

SB 6.7Ma was placed at the depth of 7150ft, as hinted by the low occurrence of microfossils and the landward shift of the SP log. This determination was matched against the Niger

Delta Cenozoic chart. It also occurs within the undifferentiated P870/P830 biozones.

The next stratigraphic surface, which is the 7.4Ma MFS was placed at depth of 7827ft. It also falls within the P870/P830 biozone. With the landward deflection of the SP log and absence of microfossils, the third sequence boundary was tied to the 8.5Ma. SB at 9063ft within the undifferentiated P820/P788 biozones. 9.5Ma Uvigerina 8 microfossils marked the fourth MFS in the well. It was defined at the depth of 10220ft. The wireline log signals show a thick condensed section. The biofacies data had high abundance counts at the depth and it fell within the undifferentiated P820/P788 biozones.

Based on the biostratigraphic data and sequence stratigraphic surfaces, ELE-1 is characterised by seven (7) lines of subdivision, depicting the alternating MFSs and SBs (Fig. 4).

CONCLUSION

This work has employed sedimentological analysis to produce lithologic section of ELE-1 Well; biostratigraphic interpretation was used to define the chronostratigraphic surfaces (Maximum Flooding Surfaces and Sequence Boundaries) which define the Third Order sequence. The litholgic sections give visual aspects of the well from shallow to deep water environments as the sediment type grades from sand to shaly lithologies. The biostratigraphic interpretation defined Maximum Flooding Surfaces and Sequence Boundaries based on microfossils abundance peaks and the signatures of the wireline logs, producing a characterization on chronostratigraphic lines of subdivision, which spells out the Third Order sequence. From the result, it is evident the tools used in this research for well based characterization are indispensable in detailed reservoir prediction in petroleum exploration.

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DISTRIBUTION AND DIVERSITY OF AVIAN SPECIES IN THREE SELECTED LOCATIONS IN THE UNIVERSITY OF IBADAN, IBADAN, SOUTHWESTERN NIGERIA

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ABSTRACT

Aves are economically important in Agriculture, acting as seed dispersers and pollinators thereby enhancing genetic diversity. They control pests' abundance by preying on insects and other pests to minimize crop damage. With the increase in the rate of climate change, research on the effects of climate change on avian distributions in Africa has become of high importance. Land disturbance also significantly affects global avian species distribution. Therefore, this study was aimed at investigating the distribution and diversity of avian species in three selected locations in the University of Ibadan (UI). Three sites were selected within UI [Fallow/Urban Land (FUL), Conserved Forest (CF), and Oil Palm Plantation (OPP)]. Birds were sampled between November 2023 and March 2024 using the Point Count method with a 50m radius. Binoculars were used for visible species and a voice recorder for audible but out-of-sight birds. Avian species composition and abundance were determined using standard methods. Diversity was determined using Shannon-Weiner index. Monthly temperature and rainfall data were collected from Nigerian Meteorological Agency (NiMet). Data were analysed using descriptive statistics, Canonical Correspondence analysis, and Bray-Curtis Cluster analysis in Paleontological Statistics (PAST). A total of 1,642 individual avian species were encountered belonging to 17 families. The families Corvidae and Columbidae were the most dominant families in the study area. The highest and lowest diversity indices were: FUL (2.271) and OPP (1.935) respectively. Temperature and rainfall ranges were 28.6°-32°C and 0-96mm respectively. Temperature influenced the abundance of *Spilopelia senegalensis, Crinifer piscator, Milvus migrans*, and *Columba* sp. While rainfall influenced the abundance of *Bubulcus ibis*. Both CF and FUL were similar in terms of avian diversity. Avian species were encountered in the University of Ibadan at low diversity. Hence, conservation efforts should focus on preserving diverse habitats and minimizing human impacts to maintain healthy bird populations.

Keywords: Avian diversity, Land use systems, Habitat fragmentation, Conservation Implications, Management strategies, University of Ibadan.

INTRODUCTION

The class Aves refers to a diverse group of organisms collectively known as birds. Birds are of high economic importance in Agriculture. It is thus, very important to identify and understand factors that can influence the abundance and distribution of the avian species. There are 23 current different orders under the class. With reclassification of some other members of the class, new orders which are yet to be universally accepted are being created (Gill, 2007). Birds are renowned for their unique adaptation of feathers, which serve many purposes such as flight, insulation, waterproofing, and display. Feathers mainly contain a protein called keratin, which is arranged in a complex structure. This complex structure of keratin allows for both flexibility and strength in birds (Wu *et al.*, 2015). Example of these birds includes; ducks, rooster, eagle, black kite, barn owl, etc.

Avian species exhibit a remarkable diversity of beak shapes and sizes, which represent the wide range of ecological niches they occupy and the diverse feeding strategies, put in place to ensure their survival. This variation in their beak morphology has been observed and studied to be

as a result of evolutionary adaptation to specific environmental challenges and resource availability (Grant and Grant, 2006).

Some birds exhibit a very strong and powerful beak which is highly useful during hunting. Birds of prey (eagles and hawks) have very powerful, hooked beaks which are well adapted for tearing flesh, while little birds such as the hummingbirds (Trochilidae family) possess long but slender beaks perfectly suited for sipping nectar from flowers (Jung *et al.*, 2018). Water-loving birds such as ducks and geese have broad, flat beaks which engineered to enhance filter-feeding on aquatic vegetation. On the other hand, shorebirds like sandpipers have slender, probing beaks which are ideal for burrowing and searching for invertebrates in mudflats (Höfling and Abourachid, 2020). The variation in avian beaks projects the importance of niche specialization and resource partitioning in ecosystems sustainability, management and in maintaining biodiversity (Höfling and Abourachid, 2020). Birds are oviparous organisms. Unlike mammals, they reproduce by laying eggs rather than giving birth to live young ones. This reproduction strategy offers many advantages which include efficient utilization of resources and the ability to disperse offspring widely. This process of bird's reproduction begins with the formation of eggs within the female's reproductive tract and stored right in the tract, after which they are fertilized by sperm from the male during copulation (Gilbert, 2014).

As oviparous organisms, birds have a key adaptation that enables their success. A key factor to this success as oviparous organisms observed in birds is the development of complex nesting behaviours and parental care strategies. Many bird species construct intricate nests to provide a secure environment for their eggs and young (e.g. Village Weaver *Ploceus cucullatus*), while others rely on cryptic egg coloration or nesting in inaccessible locations (e.g Peregrine Falcon *Falco peregrinus*) to avoid predation (Arslan and Martin, 2024). Despite these advantages of oviparity in aves, avian reproduction also poses challenges, most especially in terms of incubation and thermoregulation.

Generally, birds have evolved over time different strategic mechanisms for adaptations to their oviparous reproductive mode. This accounts for their ability to successfully reproduce and thrive in diverse environments (Martin and Mouton, 2020). Some social behaviour such as cooperative breeding and flocking, have also been extensively studied. Cooperative breeding is a situation where individual birds other than the parents help raise offspring. It has been documented in various bird species and is believed to confer reproductive and survival benefits (Koenig and Dickinson, 2016).

Migration behaviour in birds is another fascinating aspect of avian behaviour. Studies on avian foraging behaviour have revealed core feeding strategies and adaptations to resource availability. Birds have a wide range of foraging techniques, from probing and pecking to diving and aerial hawking. Each foraging technique is tailored to meet their specific dietary preferences and ecological niches (Morales *et al*., 2020).

In addition to individual behaviours, birds have interesting social interactions and networks in shaping avian communities and ecosystems. Birds engage in complex social behaviours, such as cooperative breeding, cooperative foraging, and coalition formation, which influence group dynamics and resource distribution (Farine *et al*., 2021).

With respect to the increase in the rate of climate change, research on the effects of climate change on avian distributions in Africa has become increasingly of high ecological importance. Shift in the elevation ranges of montane bird species in East Africa indicates the potential vulnerability of highland avifauna to warm temperatures. Land disturbance is another major factor in the distribution of avian species in the world. Hence, the need to understand how environmental variables and disturbance of land affect avian species distribution and diversity. This study was

aimed at determining the avian species distribution and abundance in three selected locations within the University of Ibadan, Ibadan, Oyó state, Nigeria.

MATERIALS AND METHOD

Description of Study Area

This study was carried out inside University of Ibadan, Ibadan, Oyo State, Nigeria. University of Ibadan is one of the metropolitan areas in the Ibadan North West Local Government Area, located between Latitude: 7.3912 and Longitude: 3.9167. The sample sites picked within the University of Ibadan for this survey were selected based on the land use system employed over these sites. The sites were selected to study the abundance and richness of the avian species based on the three different land use system; Conserved, Cultivated and Fallow system (Fig. 1).

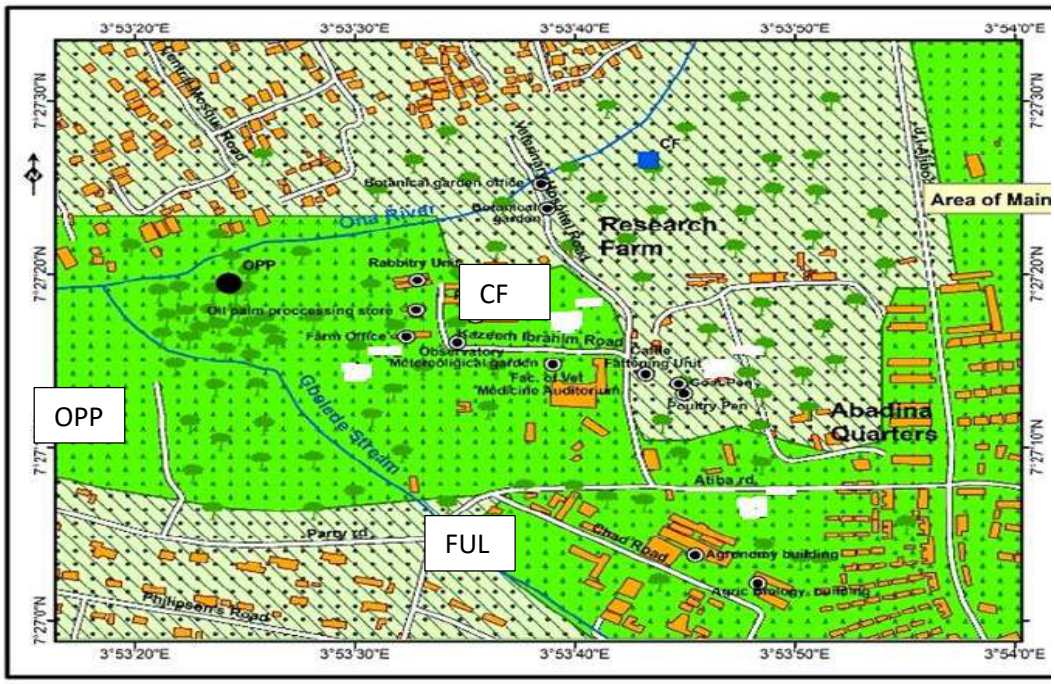

Fig. 3.1: A schematic map showing the three selected locations in the University of Ibadan Fallow/Urban Land (FUL), Conserved Forest (CF), Oil Palm Plantation (OPP)

Methods of Data Collection

Point Count Method was employed to collect data. Data were collected at specified points at the sample sites over the period of 5 months (November 2023-March 2024).

Specified points were selected across the three locations for this study. Each specified points had a circumference of 50m radius around it. Binoculars was used for the visible bird species and a voice recorder for the birds that are out of sight but audible (Zelelew and Bekele, 2008). Data on the avian species abundance were collected within this circumference. These specified points remained the same throughout the study. Data collected include avian species composition and abundance. Temperature and rainfall data were collected from Nigerian Meteorological Agency (NiMet).

Identification of the avian species encountered

Sighted bird species were confirmed through bird identification app. Merlin Bird ID and Birds of Africa were used in this task. Sounds of audible yet out-of-sight birds were examined with recorded birds from the same region to confirm the perfect match.

Birds that are out of reach fast and are not audible are examined by their feather pattern on Merlin

Bird ID for the best match. After identifying possible bird species, more attention is paid to their distinctive activities to pinpoint the exact bird species. This survey put into consideration the time of the day, the bird species, and the most preferred tree (that is, if they are resident birds). This survey was carried out between 7.00 – 9.00 hrs and 17.00 – 19.00 hrs twice in a month across the three selected sites.

Data Analysis

Data collected were analysed using descriptive statistics and percentages. Diversity and similarities were analysed using Shanon-Weiner index and Bray-Curtis Cluster analysis respectively in Paleontological STastistics (PAST). Canonical Correspondence Analysis (CCA) was done on PAST to determine the influence of environmental variables on the abundance of the avian species encountered in the study area

RESULTS

Species Composition and Abundance of Avian Species

The result of the present study showed that a total of 22 avian species were encountered across the three selected locations in the study area between November 2023 and March 2024 (Table 1). Twenty two (22) different avaian species belonging to 17 families which include: Corvidae, Columbidae, Accipitridae, Ploceidae, Turdidae, Ardeidae, Musophagidae, Bucerotidae, Alceidinidae, Phoeniculidae, Falconidae, Muscicapidae, Hirundinidae, Frangillidae, Phasianidae, Esterillidae and Cuculidae (Table 1). Of all these families, family Corvidae and Columbidae appeared to be most dominant families in the study area which account for three (3) species each. In addition, certain avian species were observed to not exist at all in a selected region. For example, Munia Bird Tricolor (*Lonchura malaccha*) was never sighted in any location except the OPP.

The Diversity Indices of the avian species in the three selected locations in the University of Ibadan (Nov 2023-Mar 2024)

The result of this present study showed the diversity of the avian species encountered in the three selected locations in the University of Ibadan between November 2023 and March 2024 (Table 2). OPP had the highest Taxa i.e. Species richness. However, despite having a richer species composition, OPP showed the lowest Shannon Weiner diversity (1.935). FUL despite having the lowest amount of species composition showed the highest Shannon Weiner diversity (2.271) (Table 2). Highest individual species was recorded in OPP (620) while the lowest was recorded in FUL (481). On the contrary, the highest evenness was recorded in FUL (0.61) while the lowest evenness was recorded in OPP (0.39).

Influence of Environmental variables on the avian species abundance in the University of Ibadan (November, 2023 – March, 2024)

The effect of environmental variables (rainfall and temperature) on the distribution of avian species were examined in this study (Fig. 2). The result showed that abundance of *Ploceous cucullatus, Milvus migrans* and *Crinifer piscator* were highly influenced by change in temperature. In addition, some avian species like *Bulbuscus ibis* and *Hirundo rustica*, were greatly influenced by rainfall (Fig. 2). However, abundance of avian species such as *Corvus albus, Lophocerus* spp, *Falco tunninculus,* etc was not affected by rainfall and temperature (Fig. 2).

Similarities among the three selected locations based on avian species diversity in the University of Ibadan (November, 2023 – March, 2024)

The result of the present study showed the similarities among and differences between the three selected locations in terms of the avian species diversity in the study area (Fig. 3). From the result, out of the three selected locations,

FUL and CF shared high similarities compared to the OPP.

Table 1: Species Composition and Abundance of the Avian Species Encountered in the University of Ibadan (November, 2023- March, 2024)

Species	Common Name	Family	Relative Abundance (%) In Each Location					
			FUL		CF		OPP	
			7:00-9:00	17:00-19:00	7:00-9:00	17:00-19:00	7:00-9:00	17:00-19:00
Corvus albus	African Pied Crow	Corvidae	45	32	07	22	18	28
Milvus migrans	Black Kite	Accipitridae	21	27	27	18	42	27
Columba spp	Pigeon	Columbidae	48	53	02	08	05	02
Spilopelia senegalensis	Dove	Columbidae	32	24	08	09	05	03
Turdus merula	Common Blackbird	Turdidae	01	00	03	00	00	00
Bubulcus ibis	Cattle egret	Ardeidae	11	20	12	12	28	02
Crinifer piscator	Western Plantain Eater	Musophagidae	05	05	02	03	06	05
Lophoceros spp	African Hornbill	Bucerotidae	16	12	19	07	21	02
Alcedo athis	Woodland Kingfisher	Alceidinidae	01	00	03	04	01	01
Falco tuninculus	Common Kestrel	Falconidae	03	02	03	00	06	01
Turtur afer	Wood Dove	Columbidae	00	00	10	12	16	13
Malimbe ibadanensis	ÌbàdànMalimbe	Ploceidae	00	01	00	00	04	00
Luscinia megarhynchos	Common Nightingale	Muscicapidae	08	18	27	21	20	04
Hirundo rustica	Barn Swallows	Hirundinidae	25	20	150	110	186	115
Crithegera spp	Seed Eaters	Fringillidae	29	16	05	09	20	15
Gallus gallus domestica	Domestic Fowl	Phasianidae	00	01	15	13	01	00
Ploceus cucullatus	Weaver Bird	Ploceidae	05	00	00	00	09	00
Lonchura Malacca	Munia Tricolour	Estrillidae	00	00	00	00	02	00
Dicrurus macrocercus	Black Drongo	Corvidae	00	00	00	00	08	04
Centropus sinensis	Greater coucal	Cuculidae	02	00	01	04	00	00
Ptilostomus afer	Pipiac	Corvidae	01	00	00	00	00	04
Phoeniculus spp	Wood Hoopoe	Phoeniculidae	00	00	00	00	00	05

FUL= Fallow/Urban Land; CF= Conserved Forest; OPP= Oil Palm Plantation

Table 2: Diversity indices of the avian species in the three (3) selected locations in the University of Ibadan (November 2023- March 2024)

	Three selected locations in the study area		
	FUL	**CF**	**OPP**
Taxa_S	17	17	20
Individual	481	541	620
Dominance_D	0.1219	0.2596	0.2656
Simpson_1-D	0.8781	0.7404	0.7344
Shannon_H	2.271	1.946	1.935
Evenness_eH/S	0.6058	0.4605	0.3846
Brillouin	2.207	1.875	1.877
Menhinick	0.7295	0.6449	0.7229
Margalef	2.429	2.225	2.644
Equitability_J	0.8193	0.7136	0.6694

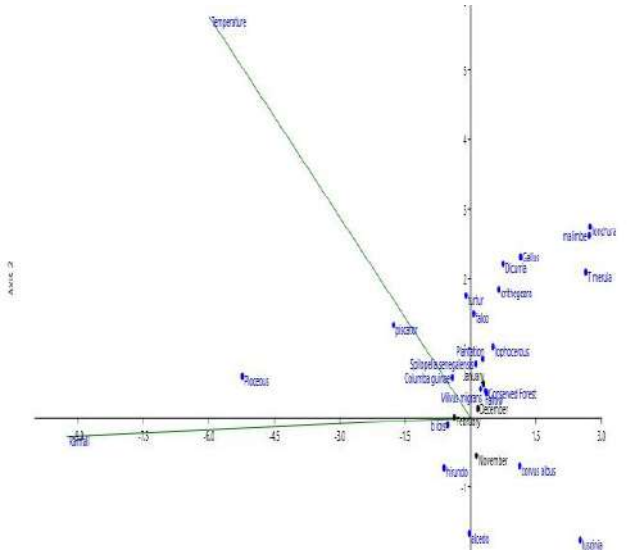

Fig. 2: Influence of Environmental variables on the avifaunal abundance in the study area using Canonical Correspondence Analysis

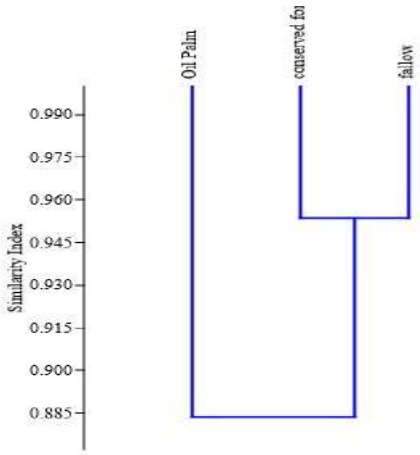

Fig. 3: Similarity index of the three selected locations based on avifaunal abundance in the study area

DISCUSSION

Avian species distribution and diversity are influenced by various factors, including food, water, and shelter availability, which vary across different study sites. Urbanization has been shown to impact biodiversity, with native species declining and urban-adapted species becoming more prevalent in urban environments (McKinney, 2008).

In this study, a total of 1,642 birds were encountered from November 2023 – March 2024. It was also revealed that a total of 22 avian species belonging to 17 different families were recorded within the University of Ibadan from November 2023 to March 2024. While a total of 22 avian species was encountered during the course of this study, the result revealed that some certain avian species were observed to not exist at all in a selected region. For example, Munia Bird Tricolor (*Lonchura malaccha*) was never sighted in any location except the OPP. This could be that the landscape and agricultural activities influence its presence. As rightly described by Amit *et al.* (2014), Munia birds are top candidate avian species commonly found around oil palm plantations.

In addition, Wood Dove (*Turtur afer*) was never seen in FUL but seen across CF and OPP. This could be that the avian species prefers a less disturbed area or regions with thick cover. This agrees with previous studies by Mikula *et al.* (2023) that every bird has a range of human disturbance that they can tolerate before they are triggered to flight. As such, *Turtur afer* was never sighted in FUL which had a very high human disturbance.

The study revealed a generally low diversity across the three selected locations in the University of Ibadan. However, FUL exhibited the highest relative avifaunal diversity (2.271), while OPP had the lowest (1.935). OPP had the highest Taxa i.e. Species richness (20). However, despite having a richer species composition, OPP showed the lowest Shannon Weiner diversity (1.935). FUL despite having a lower amount of species composition showed the highest Shannon Weiner diversity (2.271). This is because diversity is a measure of the ratio between total number of species and the total abundance in the community. Hence, the reason for the low species diversity in OPP despite having the highest abundance

This study also revealed that OPP had the highest individual species (620) while FUL was recorded to have the lowest (481). On the contrary, highest evenness was recorded in FUL (0.61) while lowest evenness was recorded in OPP (0.39). The high abundance and low evenness recorded in OPP could be as a result of the presence of few dominant species influencing the abundance of the community. This is seen in OPP having a high abundance of *Milvus migrans* and *Hirundo rustica*. This shows that the high species abundance is influenced more by the same set of species with few rare species adding to the species richness from time to time (Hillebrand *et al.*, 2008)

This study further revealed that environmental variables play a huge role in the distribution and diversity of avian species across seasons. This study revealed that some bird species are affected by temperature. Examples of these bird species include: *Ploceous cucullatus*, *Milvus migrans* and *Crinifer piscator*. In addition, some avian species like *Bulbuscus ibis* and *Hirundo rustica* are greatly influenced by rainfall. However, some birds, such as *Corvus albus* and *Lophocerous* spp., appear to be indifferent with variation to rainfall and temperature. This could be attributed to their high adaptability to different environments. This accounts for the availability and distribution of these avian species across a wide range of location and season.

Fallow/Urban Land (FUL) having the highest avifaunal diversity and OPP having the lowest posits that there's a significant relationship

between level of disturbance and avifaunal diversity. This finding resonates with previous study by Perfecto *et al.* (2014), which suggests that fallow lands can support high bird diversity by providing nesting sites, food resources, and shelter from predators. The FUL aligned with the description of Perfecto *et al*. (2014) as the trees and nesting areas of these birds are rarely disturbed when compared with the plantation site (OPP) which are constantly being disturbed by predators and chemicals used on the farm.

Studies have shown that CF should have relatively the highest avifaunal diversity among the three selected locations (Lees *et al.,* 2018). However, deforestation and other human-related activities in CF may have contributed to the low avian diversity recorded in that area. Conserved forests, characterized by minimal human disturbance and intact natural habitats, are crucial for maintaining high levels of bird biodiversity (Lees *et al*., 2018). The Conserved Forest of the Botanical Garden, University of Ibadan, experiences high level of disturbances such as heavy logging (as evident by the trees lying) and its use for parties. This must have contributed to the low avifaunal diversity observed in CF as against what was discovered by Lees *et al*. (2018). This agrees with previous study and fact that avian species are strongly repelled by anthropogenic noise (Francis and Barber, 2013).

Furthermore, this study revealed that there was spike in the total abundance of avian species during the first month of rainfall. This was evident in the increase of many avian species such as *Hirundo rustica*. This shows that rainfall greatly affects avian species abundance (Kopij, 2023). It is also possible to state that this increase in the total abundance could have been an increase in the abundance of a single species or a few.

Agricultural activities have been known to contribute to the major decline in fauna diversity globally. Large scale agricultural practices and use of chemicals have continued to play a huge role in ecosystem declination in terms of biodiversity. These agricultural activities often result into habitat loss and fragmentation, which limits the availability of suitable habitats for all living organisms including birds (Sodhi *et al*., 2009). OPP being densely involved in agricultural activities can account for its low avifaunal diversity and its relatively lowest avifaunal diversity when compared to FUL and CF.

CONCLUSION

Avian species were encountered in the University of Ibadan at low diversity. Hence, conservation efforts should focus on preserving diverse habitats and minimizing human impacts to maintain healthy bird populations.

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EXPLORING WEEDY GRASS DIVERSITY WITHIN RICE FIELDS: A CASE STUDY OF HADEJIA- NGURU WETLAND FLOOD PLAIN

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ABSTRACT

Rice fields are complex agroecosystems harboring a diverse array of plant species, including various weedy grasses. Understanding the diversity and distribution patterns of these weedy grasses within rice fields is crucial for effective weed management strategies and sustainable rice cultivation. This study aims to investigate the diversity of weedy grass species in Hadejia-Nguru wetland flood plain and assess their spatial distribution patterns for effective weed management strategies, which can enhance crop productivity and sustainability. Field surveys were conducted in a representative rice field located within Hadejia Nguru wetland flood plain during the 2023-2024 growing seasons. A systematic sampling approach was employed to collect weedy grass specimens from different microhabitats within the rice fields. Taxonomic identification and classification were performed using standard botanical keys and expert consultation. Preliminary findings indicate a notable diversity of weedy grass species within the rice field, with 16 genera and 26 distinct taxa. These species exhibit varying spatial distributions, influenced by factors such as water availability, soil characteristics, and management practices. Some species show preference for specific microhabitats within the rice field, while others exhibit a more widespread distribution. Understanding the diversity and distribution patterns of weedy grasses within rice fields is essential for devising integrated weed management strategies that minimize crop yield losses while promoting environmental sustainability. Further research is needed to elucidate the ecological interactions among weedy grass species and their impacts on rice production systems.

Keywords: weedy grasses, rice fields, diversity, spatial distribution, weed management, agroecosystems

INTRODUCTION

Rice stands as the second most significant cereal globally following wheat, with an estimated production of 520,000 kilograms in 2022 (Jones, 1995; FAO, 2022). Particularly in Africa, rice serves as a crucial source of dietary energy for numerous households, with Nigeria emerging as the leading rice producer on the continent, experiencing a remarkable 70% production growth over the past decade (Macauley and Ramadjit, 2015; Uche, 2019). This surge in production primarily stems from heightened demand and government support. Milled rice production reached approximately 5 million metric tons (MMT) in 2021, with a projected 9% increase by the end of 2022 (Boluwade, 2022). Over the past decade, rice consumption in Nigeria has surged by 4.7%, nearly four times the global consumption growth rate (Boluwade, 2022).

However, the influence of weedy grass species on rice cultivation presents a complex and multifaceted challenge. While certain grasses may pose obstacles such as resource competition and providing habitats for pests, others contribute positively to soil health and biodiversity conservation, potentially benefiting rice production in the long run. Globally,

increased rice production has often been hindered by weeds, with farmers spending a substantial portion of their production costs, approximately US $400 per hectare, on weed control during the growing cycle (Caton *et al*., 1999; Islam *et al*., 2005; Pandey, 2009).

Studies have shown that improving weed control in farmers' fields can significantly boost rice yields by 15-23%, depending on the agro-ecosystem. In sub-Saharan Africa alone, it is estimated that weeds may cause annual rice yield losses of at least 2.2 million tonnes, equivalent to US $1.45 billion (Rodenburg and Johnson, 2009). Weedy grass species in the rice fields of the Hadejia-Nguru wetland floodplain, including *Sporobolus pyramidalis, Digitaria spp.* (crabgrass) and *Echinochloa crus-galus* (barnyard grass), compete with rice for essential resources like sunlight, nutrients, and water, consequently impacting rice growth and yield (Ringim *et al.,* 2015; Mamman *et al.*, 2023).

Isma'il *et al*. (2012) identified 14 genera of weedy grass species that impact rice production in Nigeria. Yet, scant focus has been directed towards the weedy grasses growing in the Hadejia-Nguru wetland floodplain. Most research efforts have instead concentrated on Typha and its repercussions on the biodiversity and livelihoods of the wetland dwellers. Understanding the diversity and dynamics of weedy grass species within rice fields is crucial, as a balanced presence can offer ecological benefits such as soil protection, erosion control, and biodiversity enhancement. Yet, an overabundance or dominance of aggressive weedy grass species can severely compromise rice production.

Study area

Nestled in the northeastern corner of Nigeria, the Hadejia-Nguru Wetland Floodplain emerges as a breathtaking natural marvel. Encompassing a vast expanse of over 200,000 hectares, this wetland sanctuary pulsates with the rhythms of diverse life forms, weaving a vibrant tapestry of flora and fauna. Amidst its myriad treasures lies a striking array of grass species, a testament to the intricate beauty and resilience of nature's design (Mamman *et al*., 2023).

Formed by the convergence of the Hadejia and Jama’are rivers, which give rise to the Komodugu-Yobe River flowing into Lake Chad, the Hadejia-Nguru Wetland Floodplain occupies the southern fringes of the Sahel savanna. Its geographical coordinates, centrally located at 10°33'00" East and 12°39'00" North, span approximately 350,000 hectares with elevations ranging from 152 to 305 meters (Birdlife International, 2015).

Defined by a distinct seasonal rhythm, the climate of this wetland landscape transitions between two phases: the wet season from May to September and the dry season from October to April. Rainfall ranges from 500 to 600 millimeters annually, while temperatures fluctuate from a cool 12°C during the harmattan season to a sweltering 40°C in the heat of the dry season. The ecosystem's pulse is dictated by the ebb and flow of precipitation, with December to January witnessing the chill of the lowest mean temperatures and April marking the peak of scorching heat (Ogunkoya and Dami, 2007).

Characterized by an intricate network of permanent lakes and seasonally flooded pools interconnected by channels, this ecosystem serves as a vital haven for biodiversity. Particularly noteworthy is its role as a crucial habitat for migratory water birds originating from Palearctic regions, adding a global significance to its local ecological richness.

MATERIALS AND METHODS

Field survey was carried out in different Target sites within Auyo, Hadeia, Kafin Hausa, Kirikasamma, and Mallam Madori rice fields within the Hadejia-Nguru Wetlands flood plain. Standard methods have been followed for plant collection and preparation of herbarium (Jain and Rao, 1977). Plants have been identified with the help of the flora of tropical West Africa, withall habitats of the study area were surveyed

carefully. Some plant specimens were confirmed from Botany department herbarium of Ahmadu Bello University, Zaria.

RESULTS AND DISCUSSION

Present study report 18 genera and 24 species of grasses (Poaceae) (Table1). Grasses, often overlooked in the grandeur of towering trees and vibrant flowers, are the unsung heroes of ecosystems like Hadejia-Nguru. They form the foundation of the landscape, providing stability to the soil, shelter for wildlife, and essential nutrients for countless organisms. Within this wetland, an astonishing array of grass species thrives, each contributing to the ecosystem's intricate balance.

Table 1: Grass diversity of Hadejia-Nguru wetland flood plain in Nigeria

S/N	Scientific name	Local name	Vernacular name	Conservation Status	Uses
1.	*Brachiaria ramosa* (L) Stapf.	Brown top millet	Asharika	LC	fodder
2.	*Cynodon dactylon* (L.) Pers.	Bermuda grass	Kiri-kiri	LC	fodder
3.	*Dactyloctenium aegyptium* (L.) Willd	Crow foot grass	Gude-gude	LC	fodder
4.	*Digitaria ciliaris* (Retz.) Koeler	Southern Crab grass	Harqiya	LC	fodder
5	*Digitaria horizontalis* Willd	Creeping crabgrass	Harqiya	LC	fodder
6	*Echinochloa colonum* (L.) Link	Jungle rice		LC	fodder
7	*Echinochloa stagnina* (Retz.) P.Beauv.	Burgu grass		LC	fodder
8	*Eragrostis ciliaris* (L.) R.Br.	Gophertail lovegrass		LC	fodder
9	*Eragrostis tenella* (L.) P.Beauv. ex Roem. & Schult	Feather lovegrass		LC	fodder
10	*Eragrostis pilosa* (L.) P.Beauv.	India lovegrass		LC	fodder
11.	*Elytrophorus spicatus* (Willd.) A.Camus	Spikegrass		LC	fodder
12.	*Eriochloa* species			LC	fodder
13.	*Oryza longistaminata* A.Chev. & Roehr	Red rice	Roba	LC	fodder
14.	*Paspalum scrobiculatum* L.	Kodo millet		LC	fodder
15.	*Paspalidium geminatum* (Forsskål) Stapf	Watercrown grass		LC	fodder
16.	*Panicum laetum* Kunth	Panic grass	Baya	LC	fodder
17.	*Panicum subalbidum* Kunth	White Panic Grass,	Geron tsuntsu	LC	fodder
18.	*Phragmites australis* (Cav.) Trin. ex Steud.	Common reed		LC	fodder
19.	*Rottboellia cochinchinensis* (Lour.) Clayton	Itchgrass		LC	fodder
20.	*Sacciolepis africana* C.E.Hubb. & Snowden	Cupscale grass	Bubuci	LC	fodder
21.	*Setaria pumila* (Poir.) Roem. & Schult	Yellow foxtail		LC	fodder
22.	*Setaria longiseta* P.Beauv.	Bristly Foxtail		LC	fodder

23.	*Urochloa panicoides* P. Beauv.	Liverseed grass		LC	fodder
24.	*Vossia cuspidata* (Roxb.) Griff.	Hippo grass	Gwaigwaya	LC	Fodder

There are approximately more than 1800 plant species (weeds) specific to rice growing areas been recorded in the last century (Kamoshita *et al*., 2014). The influence of weedy grass diversity on rice production within the Hadejia-Nguru wetland floodplain is a topic that warrants closer examination. While there is limited research specifically addressing this issue, it is essential to understand how the presence and composition of weedy grass species may impact rice cultivation in this unique ecosystem.

One of the most prominent grass species within the Hadejia-Nguru Wetland is the *Phragmites australis,* commonly known as common reed (Table 1). This tall, slender grass dominates the wetland's marshy areas, creating dense stands that provide habitat for various pest. They have been reported as playing a key role in the development of pest swarms of locusts (Antonov and Kambulin, 1992). Bird species that may act as pest of rice (Quelea birds) are also known to hide in the dense stands of *P. australis*. Its extensive root system may impede water movement within the mini dam and water ways thereby affecting water distribution within the flood plain (Khattab and El-Gharably, 1990).

Some grass species, act as notorious weeds (*Digitaria, ciliaris, D. horizontalis, Echionochloa colonum, Oryza longistaminata, Sacciolepis africana, Paspalum scrobiculatum*, among others) that compete with rice plants for essential resources like sunlight, water, and nutrients. If left unchecked, these grasses may reduce rice yields by outcompeting rice plants for resources. On the other hand, certain grass species, like the *Panicum laetum*, can contribute to soil stability and nutrient cycling, which may benefit rice cultivation (National Research Council, 1996). These grasses help prevent soil erosion, retain moisture, and improve soil fertility, creating a more favorable environment for rice growth.

CONCLUSION

The impact of weedy grass species on rice cultivation is complex and multifaceted. While some grasses may pose challenges such as resource competition and habitat for pests, others contribute to soil health and biodiversity conservation, which can benefit rice production in the long term. Protecting the diverse grass species within the wetland ecosystem is essential for maintaining overall ecosystem health and biodiversity, which can indirectly benefit rice cultivation. Healthy ecosystems support natural pest control, pollination services, and nutrient cycling, which can enhance rice productivity in adjacent agricultural areas. This study has tried to decode the different grass varieties found in the Hadejia-Nguru Wetland Floodplain rice fields. While inventorying the grass diversity, about 23 weedy grass species (Family-Poaceae) were documented. The present work will form the base for future conservation strategies pertaining to grass resources, which are primarily valuable as fodder for local wild as well as domestic animals.

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EFFECTS OF RADIO FREQUENCY RADIATION ON THE GROWTH AND DEVELOPMENT OF SELECTED CROPS IN BAUCHI STATE, NIGERIA.

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ABSTRACT

Mobile communication and internet surfing have become an integral part of everyday life. The use of the internet via phones and computers has dominated almost every aspect of human life. The ever-increasing use of antennas and wireless devices, including routers, increases the electromagnetic radiation exposure of living organisms, including plants. This research evaluated the effect of radio frequency radiation on the germination and vegetative growth of selected crops grown in Bauchi. Certified seeds of four selected crops of economic importance (Tomato, Pepper, Corn, and Okra), were obtained from Bauchi State Agricultural Development Program (BSADP) in Bauchi State, Nigeria. Three wooden screen houses, each of dimension 2 m by 2 m was constructed at the experimental site. The houses were placed at distances of 15m, 25m and 50 m away from the selected communication masts. Growth parameters including leaf number, plant height, leaf length leaf width were recorded on a 2-week basis. Seeds of corn, tomato and okra almost germinated at the same time (about 6 days after planting) while seeds of pepper delayed to about 13 days after planting. All the parameters observed were found to be affected by the radiation depending on the distance to the mast as compared to the control. The radiation effects tends to reduce as one move away from the mast. Therefore, this research recommends that there should be no crops cultivation under or close to a communication mast.

Key Words: Electromagnetic radiation, Mast, Radio frequency, Crop performance,

INTRODUCTION

The incessant increase in the use of mast and wireless devices including routers increases the exposure to electromagnetic radiations of living organisms which includes plants. Electromagnetic radiation consists of electromagnetic waves, which are synchronized oscillations of electric and magnetic fields that travel through a vacuum at the speed of light (Alattar and Radwan, 2020). Electromagnetic waves are a form of radiation within the range from high-energy cosmic and gamma rays to a low energy microwave radiation and radio waves (Wdowiak *et al.*, 2017). Living beings are embedded with both artificial and natural electromagnetic radiations. Natural radiations are generated from three sources: 1) cosmic radiation, 2) terrestrial radiation, and 3) internal radiations (Desouky *et al*., 2015). While artificial radiations are generated by radio communication, communication satellites, computer networks, broadcasting, and radar (Alattar and Radwan, 2020). The influence of electromagnetic radiation on living systems depends on the properties of exposed tissue, power level, exposure duration, frequency, and pulsed or continuous wave (Alattar and Radwan, 2020).

It has been reported that electromagnetic radiation affects essential physiological processes of exposed plants such as respiration, long-distance transport (Kebeish *et al*., 2015; Alattar and Radwan, 2020), photosynthetic pigments, photosynthesis, (Kumar et al., 2017), the functioning of the hormonal system, antioxidant system of irradiated plants, mitotic division process as well as genetic regulation of physiological processes (Noctor *et al*., 2018; Alattar and Radwan, 2020). Though this radiation affects the functioning of living organisms, exact knowledge of the effects is insufficient. Recent studies reported a lot, relating the problem of the effect of electromagnetic radiation on living systems, seeking in them both positive and negative effects (Alattar and Radwan, 2020). This research is aimed at evaluating the effect of radio frequency radiation on the germination and vegetative growth of selected crops grown in Bauchi.

MATERIALS AND METHODS

Experiment was conducted to determine the effects of radio frequency- electromagnetic radiation on four selected crops of economic importance: Tomato, Pepper, Corn and Okra. Certified seeds of the selected crops were purchased from the seed multiplication unit of Bauchi State Agricultural Development Program (BSADP) Bauchi State, Nigeria.

Experimental Design

Three wooden screen houses of 2m by 2m were constructed at the experimental site with a bench of about 1m above the ground (a point at which maximum radiation is received) and covered with transparent plastic roofing sheet which allows both sun light and the RF radiations to pass through. The houses were placed at distances of 15m, 25m and 50m away from the selected communication masts (Figure 1).

The experimental design was in accordance with the method descried by Alattar and Radwan (2020). Here, four different crops (Tomato, Pepper, Corn and Okra) were planted and raised in a nursery bed for two (2) weeks and were later transplanted into 1 liter plastic pots containing a mixture of sharp sand and topsoil (Figure 2). The seedlings were grouped into four (4) groups of six (6) replications each, three of the groups were exposed to the RF-EMF radiation in the screen houses at the experimental site at distances of 15m, 25m and 50m respectively. The fourth group was left without radiation as the control of the experiment. The crops were watered daily.

Crops growth parameters including leaf number, plant height, leaf length leaf width was recorded on 2 weeks basis.

Data Analysis

Minitab 17 (Minitab Inc, USA) was used for data analysis. Where required, data that were not normally distributed were square root transformed before statistical analysis. Two-way analysis of variance (ANOVA) was used to test the effect of radiation with distance from the radiation source on the difference crops. The interaction between the different crops and distance, was tested using a General Linear Model (GLM) with two factors, crops and treatment (varying distance).

Figure 1. A photograph of the screenhouse used for the study

Figure 2. Experimental setup

RESULTS

Effect of radiation on plants seeds germination

The four crops varied in their response to the effect of radiation on seed germination. The seeds of corn, okra and tomato germinate nearly at the same time (at six days after planting) while the germination of pepper seed was delayed to about thirteen days after sowing. However, the general effect of radiation on seed germination depends on distance as shown in (Figure 2). The control and the plants planted at 50m germinated earlier than those at 25 and 15m which are closer to the source of the radiation.

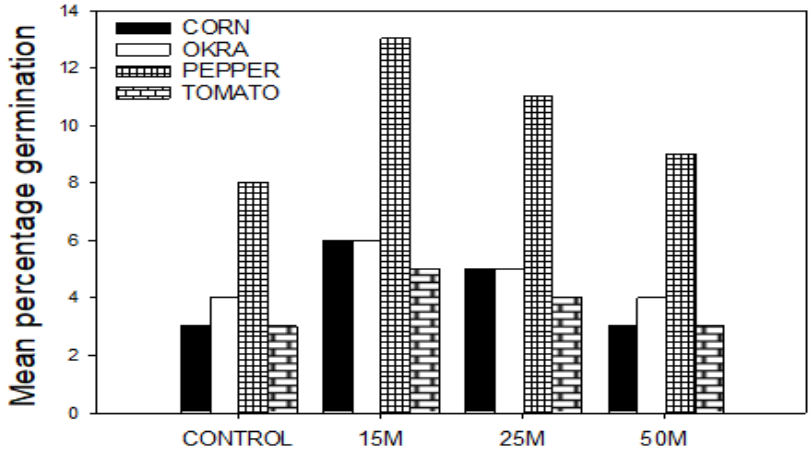


Figure 3: Effects of radiation on crops seed germination with distance from radiation source

Effect of radiation on crops growth parameters

Effect of radiation on crops height

The summary of the effect of radiation on plants growth is shown in Table 1. Plant height was significantly ($P < 0.001$) reduced by radiation in all the tested crops compared to the control treatments. There was a significant difference between the crops by treatment (distance) interaction showing the reduction in height was as a result of the radiation (Table 1). However, the effect of radiation on distance from the sources differed among the different crops. The height of crops planted at 50 and 25 m were significantly reduced compared to the control and crops planted at 15m from the radiation source (Figure 4). This observation is in contrast to Pepper where height was not affected in crops planted at 25m compared to control and other treatments. The effect of radiation on height was greater in corn planted at 25m compared with the rest of the distance. In Okro, the different

distance has no effect on height. In tomato height was reduced in relatively similar manner in the treatments as compared to the control crops.

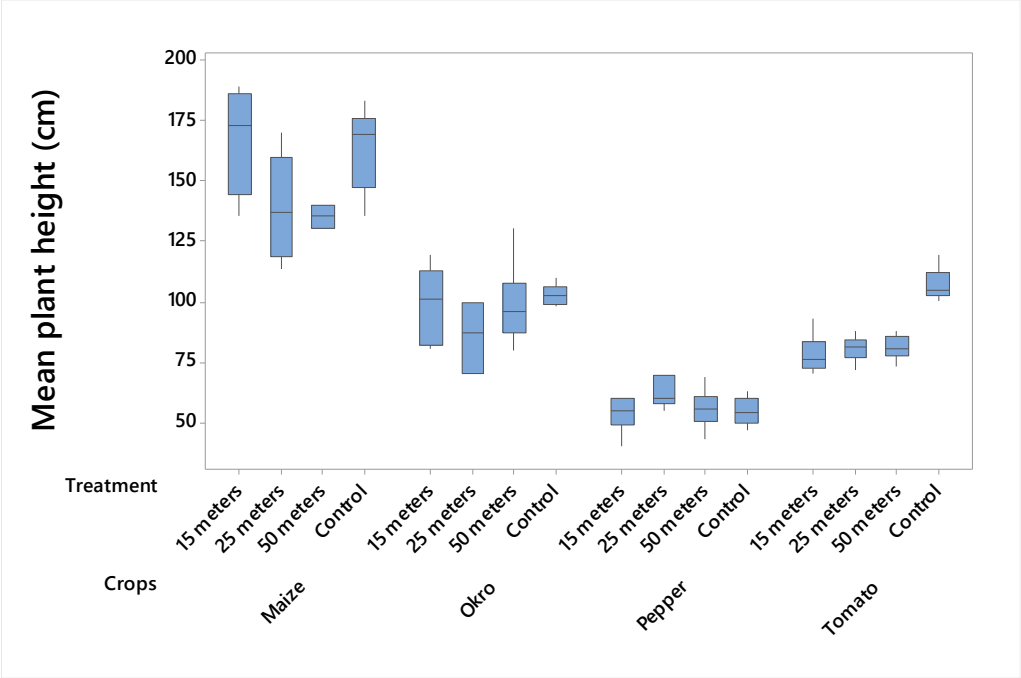


Figure 4: Comparative effect of radiation on crops height with distance from the source of source of radiation

Table 1: Effect of radiation with distance on plant height, leaf number, leaf length, leaf width and number fruits (yield)

Crops	Distance	Plant height cm	Leaf No. /plant	Leaf length /plant	Leaf width cm	Fruit No. (yield) /plant
Corn	Control	163.3±17.21	14.00±1.55	11.13±7.44	8.57±1.07	1.00±0.00
	15 m	167.3±22.77	16.00±2.16	70.875±4.300	7.6±0.762	1.00±0.00
	25 m	138.8±21.9	15.00±1.26	70.2±3.33	6.47±0.41	1.00±0.00
	50 m	135.3±4.86	15.00±1.00	76.8±5.77	9.77±0.68	2.00±0.00
Okro	Control	102.62±4.29	16.00±0.89	41.2±2.92	17.5±1.89	4.00±0.89
	15 m	99.05±13.94	17.00±2.97	39.5±5.11	17.78±1.68	2.00±0.89
	25 m	85.42±13.94	18.00±2.97	32.78±2.04	16.18±1.52	4.00±0.89
	50 m	98.57±17.05	17.00±2.68	33.77±4.20	15.07±2.36	3.00±0.89
Pepper	Control	54.78±5.92	47.00±5.09	24.68±9.24	7.25±2.17	6.00±0.89
	15 m	53.68±7.49	90±28.00	20.72±2.29	7.07±0.74	5.00±2.37
	25 m	62.27±5.90	60.00±9.89	21.28±4.97	7.03±1.26	7.00±1.09
	50 m	55.65±8.34	56±20.39	19.37±4.96	6.80±1.10	7.00±3.09
Tomato	Control	106.77±6.81	49.00±5.25	44.32±5.07	7.72±0.52	14.00±2.00
	15 m	78.00±8.04	44.00±9.96	28.4±3.83	4.92±0.39	9.00±2.76

	25 m	80.63±5.54	49±10.9	30.87±3.36	5.35±0.48	9.00±0.89
	50 m	81.03±5.06	53.00±10.95	29.85±2.2	6.18±0.24	10.00±1.67
NOVA				F values		
Crops		208.25***	109.66***	421.77***	339.33***	132.47***
Distance		7.73***	3.49*	13.87***	5.51**	5.80**
Interactions		3.81***	4.99***	2.76**	3.60***	3.68**

Data presented for plant height, leaf number, leaf length, leaf width and number of fruits (yield) are means of six replicates. The significance of a treatment effect was calculated by a three-way ANOVA for each crop, and Turkey's pairwise comparisons (***, P≤ 0.001; **, P≤0.01; * P≤0.05)

Effect of radiation on crops leaf production

The result of the analysis of variance on the effect of radiation on the crops showed a significant crop and distance effect. Leaf number production was significantly (P <0.001) higher in pepper followed by tomato and lowest in okro and corn (Figure 5). Similarly, the effect on radiation with distance was only significant in pepper, followed by tomato, and lowest in Okro and corn (Figure 5b).

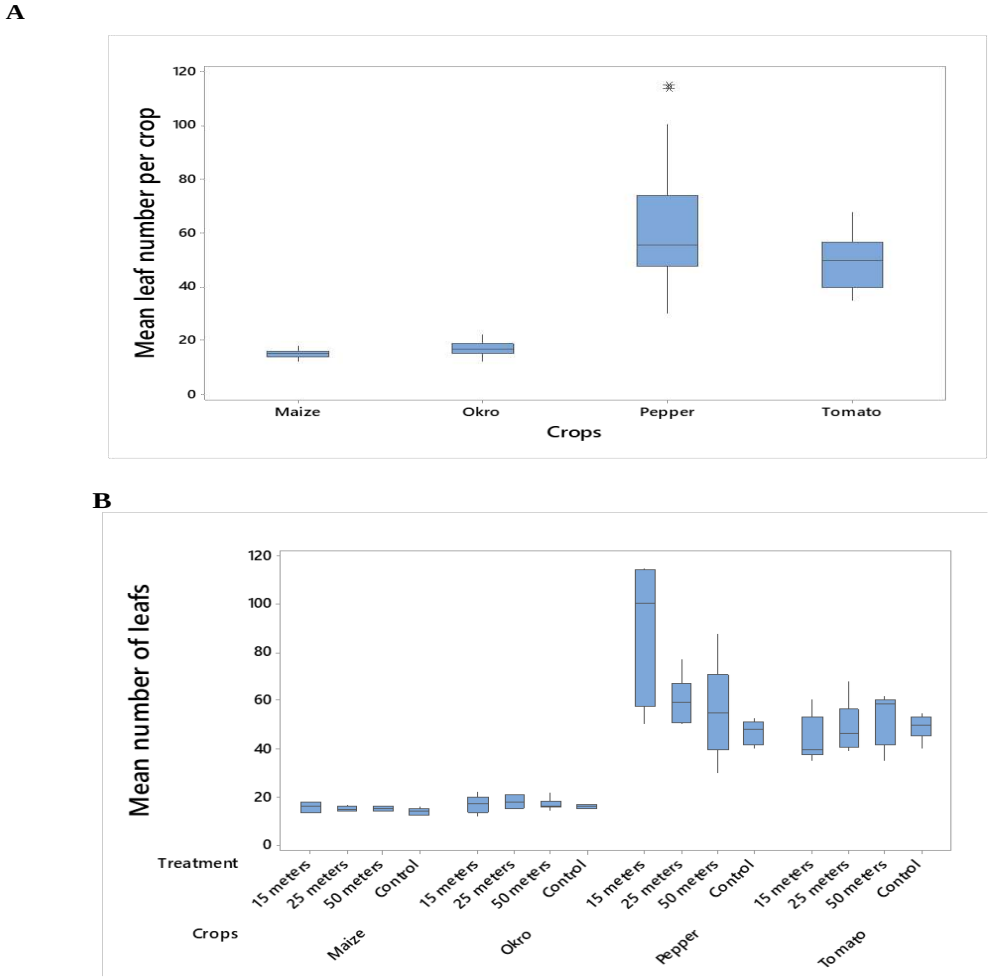


Figure 5. Shows the effect radiation on leaf number production with, A) between the crops and, B) with distance, compared with the respective control treatments.

Effect of radiation on crops leaf length

All the tested crops differed significantly (P<0.001) in their response to the effect of radiation on leaf length. This effect was higher in pepper followed by okro and tomato, lowest was observed in corn (Figure 6). The effect of the radiation with distance from the source greatly (P<0.001) reduced leaf length among the three treatments (distances) as compared to the control crops. At the same time there was a significant difference in crop by distance interaction, showing that the reduction in leaf length was due to effect of the radiation

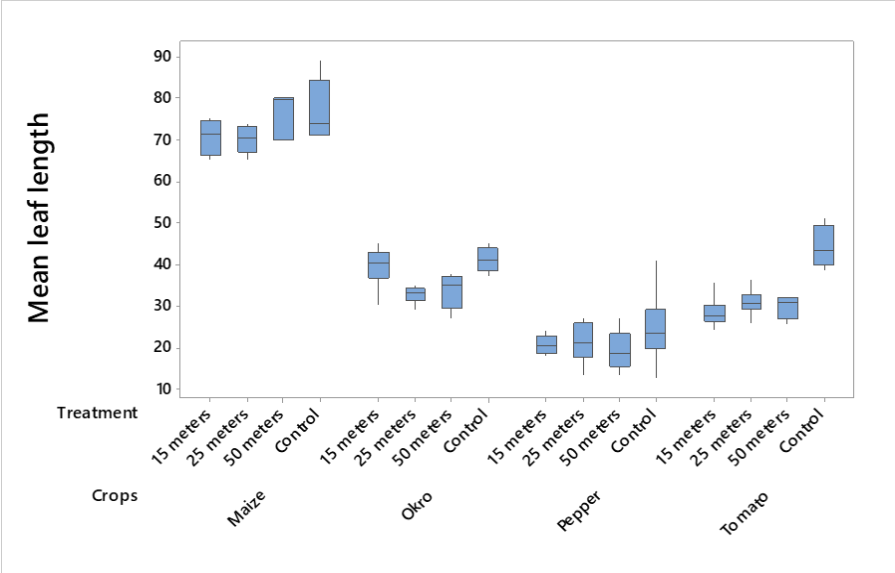
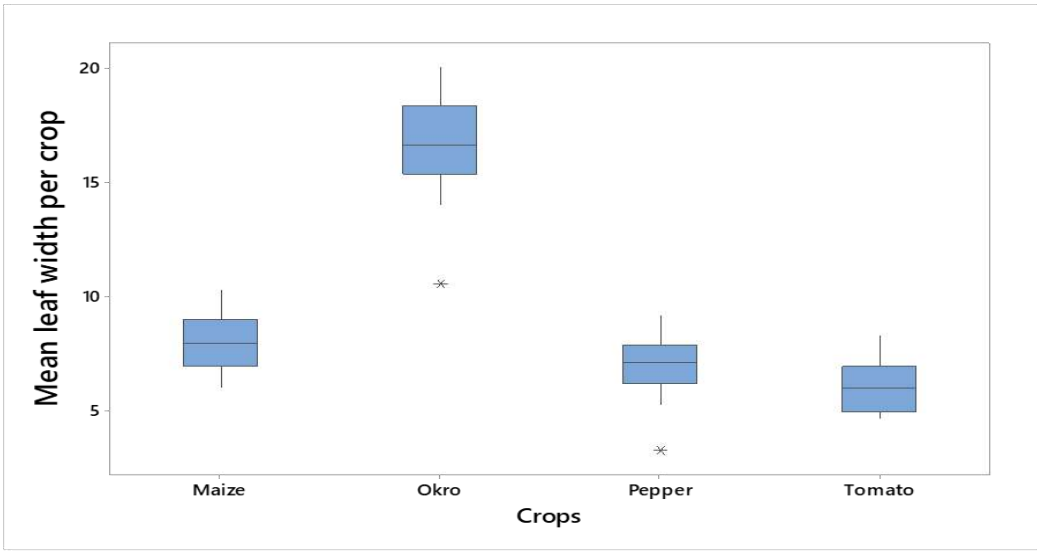


Figure 6: Comparative effect of radiation on leaf length with distance from radiation source

Effect of radiation on leaf width

Radiation significantly (P<0.001) affects leaf width in all the tested crops. Leaf width was severely reduced in tomato compared to corn and pepper. The least reduction in leaf width was recorded in okro (Figure 7a). Moreover, the effect of radiation with distance was only significantly different between the control and crops planted at 25m distance (Figure 7B).

A



B

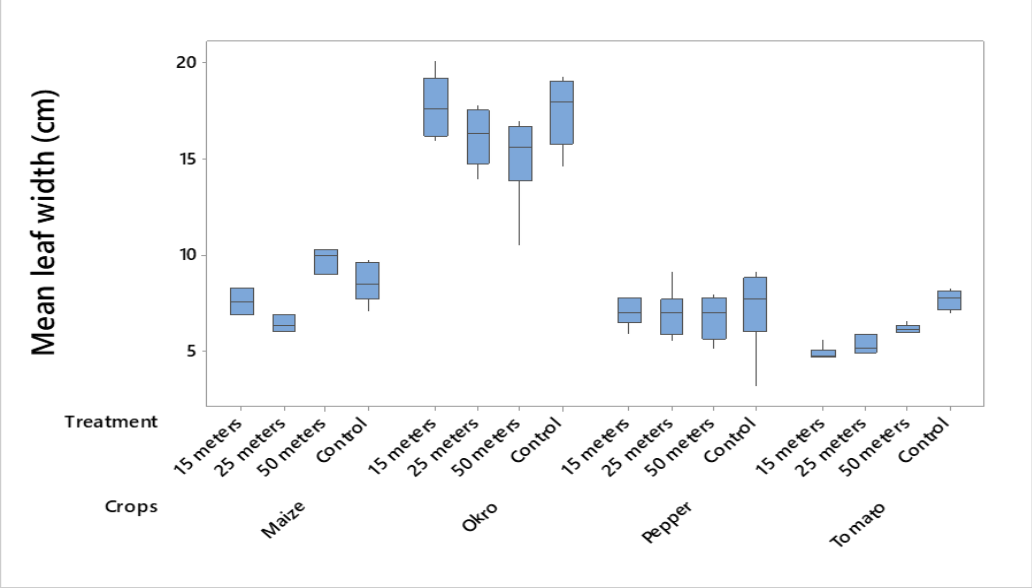


Figure 7. Effect radiation on leaf width with, A) between the crops and, B) with distance, compared with the respective control treatment

DISCUSSION

The study investigates the effect of radiation on the germination, development, and amino acids profile of four different crops. The four crops studied showed very different responses to radiation. Radiation significantly affects nearly all the traits' studies. However, this effect differs with crops and the distance from the source of the radiation (Table 1). The results showed that radiation exposure for a long term has a pronounced restrictive effect on the seed germination of pepper. Pepper seed takes relatively twice duration to germinate than the seeds of the rest of the crops. This effect depends on the distance from the radiation source as shown in (Figure 3).

Crops height was significantly (P<0.001) reduced by radiation in all the tested crops compared to the control treatment. The height of crops planted at 50 and 25 m were significantly reduced compared to the control and crops planted 15m from the radiation source (Figure 4). This reduction was caused by the radiation as indicated by the significant (P<0.001) difference observed in crop by distance interaction. However, this effect was not observed in pepper and corn, demonstrating genotypic variation on the response of the different crops to radiation.

The analysis of variance on the effect of radiation on leaf production showed a significant difference in crop by distance effect. Leaf number was significantly (P <0.001) higher in pepper followed by tomato and lowest in okro and corn (Figure 5). Similarly, the effect of radiation with distance was only significant in pepper, followed by tomato and lowest in Okro and corn (Figure 5).

The effect of radiation on leaf length was higher in pepper followed by okro and lowest in corn (Figure 6). This effect was distance dependent and greatly (P<0.001) reduced leaf length in all the three treatments (distances) as compared to the control crops. At the same time there was a significant crop by distance interaction showing the reduction in leaf length was due to effect of the radiation.

The impact of radiation on leaf width showed a higher genotype dependent effect. Leaf width was severely reduced in tomato compared to corn and pepper. The lowest reduction in leaf width was recorded in okro (Figure 7A). Moreover, the reduction was only different between the control and crops planted at 25m distance (Figure 7B).

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ASSESSMENT OF SOIL POTENTIAL EFFICIENCY FOR WETLAND UTILIZATION IN WUSHISHI LOCAL GOVERNMENT AREA OF NIGER STATE, NIGERIA

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ABSTRACTS:

This study focuses on the soil potential efficiency of Wetland utilization in Wushishi local government area of Niger State to assess the potential capability of soil regarding crop production in the wetland; to quantify and evaluate magnitude of wetland soil potentials using Remote sensing data, and laboratory analysis, and to compare heterogeneous nutrient data to predict the soil capability and potentials for crop production. The study utilised laboratory tests and GIS integration of heterogeneous nutrient data to effectively state and predict the soil capability and potential to ensure crop production improvement. The findings show that there are more wet years than dry years, indicating about 13.39% annual increment of land utilization with normal annual precipitation distribution. The statistical analysis indicated an annual increasing trend of 0.1339 with an R2 value of 0.33. It was discovered that farming activities in the area increased from 37.12% in 1992 to 48.9% in 2022. Only the Maito area is cultivated by subsistence farmers. The study concludes that the Zungeru camp, Tunga Kawo and Wushishi areas has suitable soil potential for farming ranging from 58.0 – 97.0 with soil/water potential pH of 7-10 and 6-9 moles respectively. This indicates that the area is not acidic but suitable for cultivating cereal crops like rice, maize, and grains. The topographic setting of the Bankogi area which is steep-sloped, lacks vegetation, and is currently not suitable for any agricultural activities. The study area consists of wetlands suitable for cultivation in all seasons.

Keywords: Heterogeneous nutrients, Soil capability, Wetland utilization, Soil potential efficiciency, Wetland soil

INTRODUCTION

Wetlands serve as area for fishing and different forms of recreation. Wetland ecosystems are important environmental and natural resources contributing to the total wealth of a nation. However, because many of its services are not traded in the open markets and their values are not captured using the conventional approaches to valuation, they are usually ignored in the systems of national accounts. As a result, conventional measures of wealth give incorrect indications of the state of its well-being, leading to misinformed policy actions and poorly informed decision-making.

The water table of wetlands is near the land surface with high level infiltration and overflow of water as well as reservoir for flood retention. According to Barbosa (2009), wetlands were previously seen as dirty, dangerous and unimportant areas; while Barbosa (2010) opined that they are complex ecosystems hosting a high diversity of landscape associated with water, soil and vegetation variations. Wetlands are great resources for life on earth especially mankind who depend on wetlands for survival (Ibrahim and Nwaerema 2020). Wetlands are habitats for different species of plants and animals on earth (Barbosa, 2010). Due to the high saturation of water in a wetland, it has become a life support system that supplies the water needs of the numerous biodiversity of plant and animals for their existence (Ramsar, 1998). The huge resources in wetlands, have sometimes turned it

to be areas of strong disputes among community farmers and herdsmen. Therefore, it has become imperative to design good wetland management framework for sustainable use of the abundant resources. According to Nigeria National Root Crops Research Institute (NRCRI, 1993; 1995), the awareness of dry season vegetable cultivation is growing in both north and southeastern agricultural zones of Nigeria. However, the wetlands are usually utilized in planting rice, sugar cane, cocoyam (*Colocasia spp)* and early yam *discorea spp* in the zone. Fishery is practiced along some river channels. There is limited studies conducted on the wetlands in some ecological zones of the river basins (Lekwa, 1986). River basin development authorities have reported the challenges of wetland in southern part of Nigeria (Enwezor et al. (1990). Also, some geological soil study however was understudied by Obaje, (2012) and Olasehinde (2010). Many wetland studies have been carried out by some scholars (Jungerius, 1964; FDALR 1985; Ohiri et al., 1989; Mbagwu, 1990). The objective of this study was to delineate and characterize the wetland soils utility and its impairment to development in Niger State. The results would serve as a management tool for sustainable wetland development and management.

MATERIALS AND METHODS

Wushishi is a Local Government Area in Niger State, located between Longitude 9°42' and 7.20''N and Latitude 5°56' and 11.83''E. The Local government is bordered by Gbako and Katcha local government at south Eastern side, Rafi at North western side, Chanchaga at North Eastern part of Niger state.it is habited by an estimated population of about 200,900 people with an area of 1,879 km² and a population of 229,449 (National Bureau of Statistics 2016). The local government is drained by River Kaduna which is perennial and river Tunga seasonal. Dams are constructed across the rivers and are majorly used for both domestic and agricultural purposes. The wet season sets in from March and April reaching its climax by August and September. And ceases by October. The dry season sets from middle October till March of the following year. It has an annual rainfall of about 1150 mm with mean annual temperature of about 27.7° C.

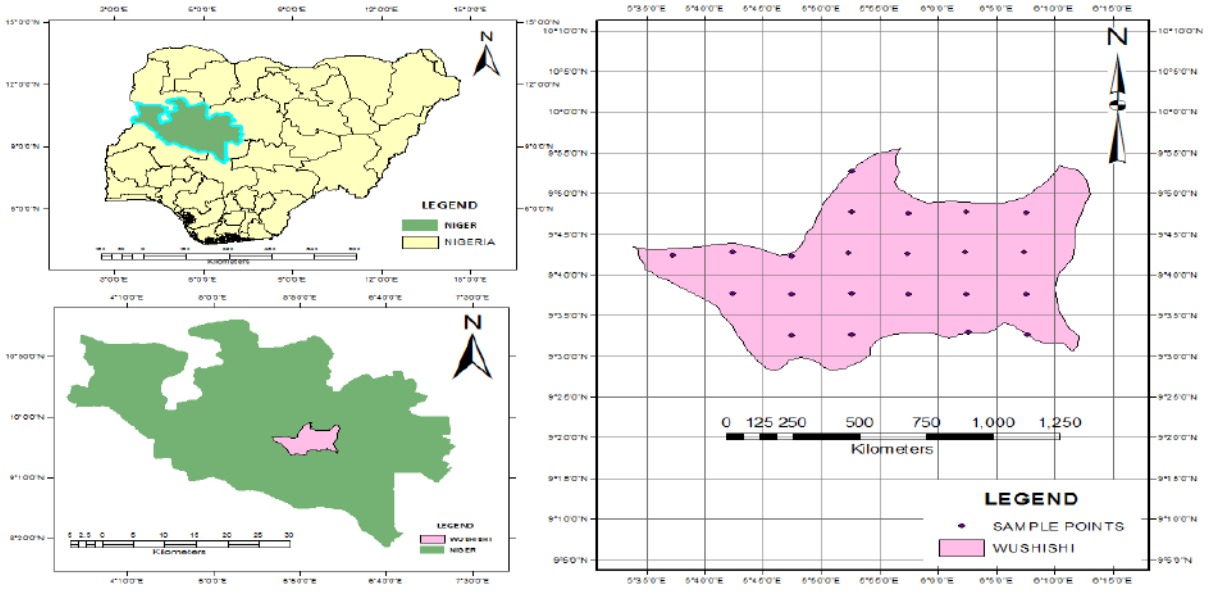

Figure 1: Geographical location of Wushishi local government area of Niger State, Nigeria

This study utilized the potential of laboratory test and GIS integration of heterogeneous nutrient data to effectively state and predict the soil capability and potentials in order to ensure improvement in crop production. The effectively achieved potential capability of soil regarding crop production in the wetland is quantified and evaluated based on the magnitude of wetland soil potentials. The study area was demarcated according to the geo-political wards (districts) of the Local government. Soil samples were collected from fifteen points and taken for laboratory analysis. There are six wards consisting of Wushishi, Zungeru, Maito, Tunga Kawo and Bankogi districts. From each district, three points were sampled for the soil analysis depending on population and land mass of the district, areas within flood plain, developed and farmlands. Bulk soil sample were collected and taken to laboratory for soil analysis. Satellite imagery of three decades (1992-2022) were used in presenting relative manner of wetland utilization processes in the study area. The area is basically drained by two rivers, River Kaduna. From all the literatures reviewed on this section one of the most challenges encountered are problem of estimation, maintenance and management of land use in different part of the world.

RESULTS AND DISCUSSIONS

Some noticed examples that emanated from projected extreme climate change events include flow base changes, wildlife is stressed due to increase in heat generation, potential increase of flooding, landslide occurrences, soil erosion become real (STRP 2002). With the recent predicted climatic scenarios of the future, exotic spread possibly enhanced that increase pressure on watersheds ecosystem, Climate change is expected to react in relation with some other pressures many of these pressures depend on the regional condition which pose a lot of danger on the water resource in relatively short term (Root et al. 2003). Other factors related to climate play key role in determining the impact on wetland environment which include temperature, alteration of biogeochemistry, fire, organic sediment oxidation and wave energy effect (IPCC, 1998; Burkett and Kusler 2000; USGCRP 2000). Water resource of a particular wetland ecosystem is largely affected by climate condition as tempted by fluctuation in precipitation and temperature over time. From views of climate variability bases and effect, it poses on wetlands, these numerous ecosystems needed to be viewed in a broader way of their spatial location within a region. Wetland preservation and loss are one of the major predicament nations around the globe faces in this century. Nations like Nigeria, USA and china have shown a lot of concern over the issue because they have undergone series of development in aspect of wetland conservations. It was noticed that economics plays the most important role when it comes to wetland development to produce food, shelter and water. This indicated how much the wetland in Niger State lack sound and widespread research and when this is lacking it is difficult to make decision regarding protection and conservation.

Identifying the extent of wetland to achieved potential capability of soil potentials regarding to crop production in the study area, three decades of Land SAT satellite imagery are established by looking at the land use/land cover over 30 years in the local government.

Three set of Land-SAT imagery are adopted across the 30 years 1992-2022.

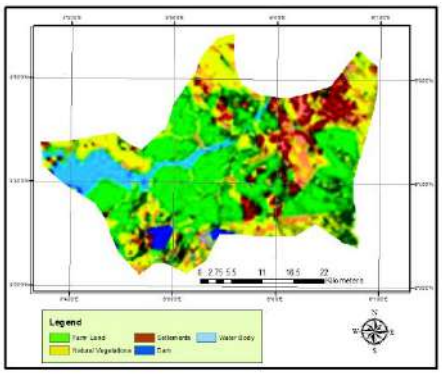

Fig 1: Land use in 1992

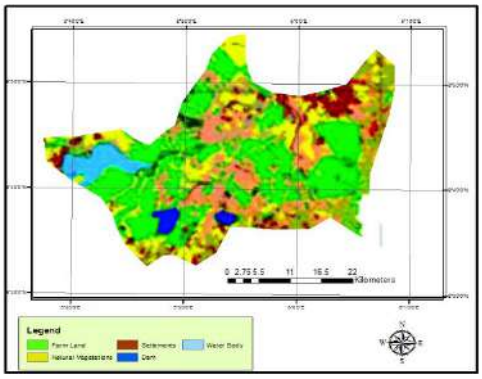

Fig.2: Land use in 2002

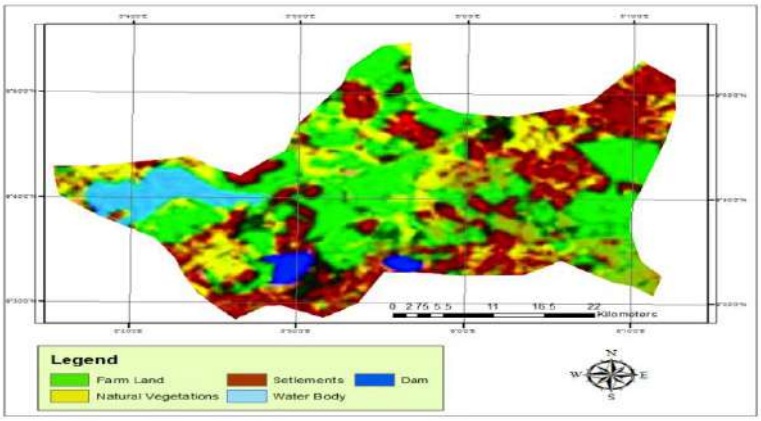

Fig. 3: Land use in 2022

Table 1 : Land Use/Land Cover in 1992

Land use	Area in Hectares	Percentage (%)
Natural Vegetation	17417.964438	47.14
Wetland	2292.769584	11.21
Farm Land	7865.115636	37.12
Settlement	555.660294	2.63
Water body	371.88541	1.9
Total	20267.00	100

Researcher's Analyses, 2020

The estimation of land-use analysis shown in fig. 1 indicated that in 1992 the predominant land-use is natural vegetation which accounted for 17417.96 hectares (47.14%) of the study area. Settlements occupied only 555.66 hectares (2.63%) while Farm land occupied 7865.11 hectares (38.81%); water body occupied 371.88541 (1.9%) and wetland occupied 2292.76 hectares (11.12%). This shows that at this period, the inhabitants of the study area were few in number and their occupation then was farming and hunting and other primary activities.

The Table 2 and Figure 2 revealed that farming activities in the area increase from 37.12% in 1992 to 48.9% in 2002, Natural vegetation decrease from 47.14 in 1992 to 32.76 in 2002

Table 2: Land use/land cover in 2002

Land use	Area in Hectares	Percentage (%)
Natural Vegetation	4193.078175	32.76
Wetland	7709.2272	11.21
Farm Land	5806.369125	48.9
Settlement	2552.008275	5.23
Water body	4193.078175	1.9
Total	20267.00	100

Author (2000)

Table 3 : Land use/land cover in 2019

Land use	Area in Hectares	Percentage (%)
Natural Vegetation	1193.078175	12.15
Wetland	7709.2272	9.43
Farm Land	7906.369125	65.2
Settlement	2552.008275	11.32
Waterbody	4193.078175	1.9
Total	20267.00	100

Researcher's Analyses, 2022.

The study area in 2019 shown in Figure 3 and Table 2 indicated that natural vegetation has decreased to 12.15%, and Farm land increased from 48.9% to 65.2%, while settlements increased from 5.23% to 11.32%. The water body remained at 1.9%. It was observed from the analysis in Figure 4.6 that, farmland has expanded from part of the western part of the study area to the northern part through the eastern part of the area, most of the natural vegetation in 1989 has been opened up for farming activities.

Variation in contents of soil at different locations

Analysis results of the soil content were computed at different locations in the study area, the parameter analysis were pH H20, pH CaCl2, Condt,%TON, %OM, Nacoml/kg, kcmol/kg and Cacmol/kg. The samples were taken from six sample sites, Zungeru camp, Wushishi town, Tunga Kawo dam, Bankogi, Maito and Tshohon-dabiri. Analysis in Table 7 shows the results of soil sample analysis of Bankogi as the highest *p*H. H2O value of 7.84 follow by Maito with 7.65, Zungeru camp with 7.39 while Wushishi town has the lowest with 6.27. The soil pH of the study area ranged from 6.47 to 7.84 and was rated as "strongly acidic" to "moderately acidic" as per the soil *p*H classification by Tekalign and Tadesse (1991). The analysis showed a significant difference in soil parameters from locations ($p < 0.01$) and soil depth ($p < 0.05$) while there were no differences due to interaction effect. Significantly higher was recorded in cultivated land and grazing lands. Nevertheless, no significant difference ($p > 0.05$) was observed in the parameters among land use type and soil depth.

The increase in clay content and a decrease in the sand and silt fractions in the lower soil layers could be attributed to the downward migration of clay particles in the soil profile as evidenced by its higher contents in Mgcmol/kgthat ranges between 0.8-1.22; Sand percentage ranges between 52-66; Clay percentage ranges between 9-17 and the selective removal of finer soil particles from surface soils by erosion leaving

behind the coarser fractions. It was higher clay content in lower soil depths and forest land than the cultivated and grazing lands.

Map areas of potential wetland soils for agricultural practices using Remote sensing technique

The suitability for potential farm land range from 58.0 – 97.0 while 3.0-57.9 are not suitable for any agricultural activities. Moreover, areas within the ranges of 85.1 to 97.0 are characterized with wetland properties due to the presence of lake and soil condition that is capable to retain water at high potential. The (NIR) over the growing period between 830 and 1630 mm/year (Figure 4.9). From the figure, lowland area characterized with higher NIR where the temperature is high for the growing period.

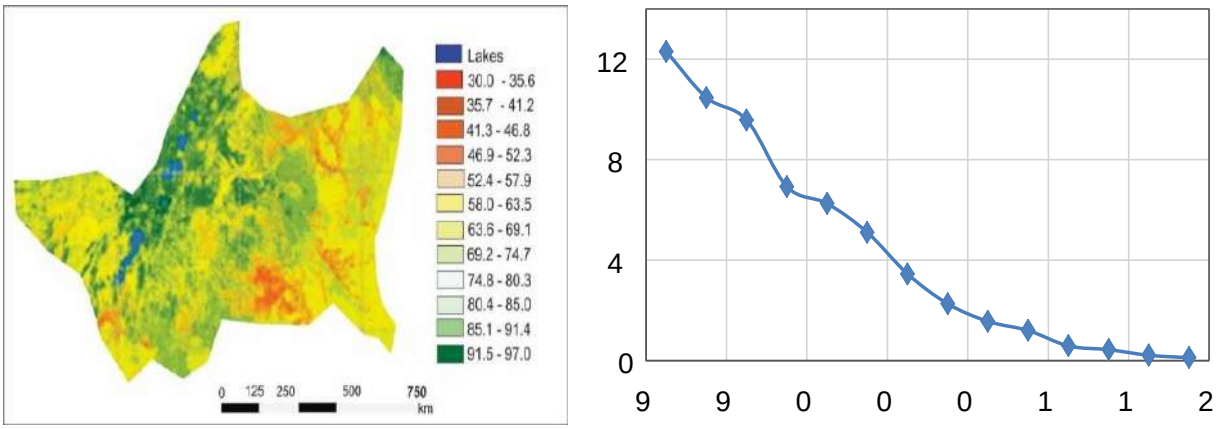

Figure 4: Potential and suitable areas

Sources: Fieldwork 2022

The Table 4, depicts that Bankogi has the highest pH. CaCl2 of 6.76 follow by Zungeru Camp with 6.55 while Wushishi town still has the lowest value of pH. CaC l2 with 5.49. it was also discovered from the analysis that Tunga Kawo dam has the highest Namco value of 0.24 and Maito has the lowest with 0.16. Zungeru camp has the highest Cacmol value of 3.15 while Maito has the lowest with 2.5. The analysis signifies that soil samples varies from one site to the other.

The physicochemical parameters of the soil were also analyzed based on the different locations in the area, the variations in the parameter tested depicts that Zungeru camp has the highest Mgcmol, Wushishi, Tunga Kawo dam and Tsohon dabiri has the highest value of Exch A (0.06), but Wushishi town has the highest percentage of sandy soil, Tunga-Kawo dam has the highest clay while Zungeru camp has the highest silt.

Table 4: Results of Soil Sample from the study area

Sample points	pH. H2O	pH. CaCl2	Condt	%TON	%TOC	%OM	Nacmol/kg	Kcmol/kg	Cacmol/kg
Zungeru Camp	7.39	6.55	84	0.38	0.98	1.68	0.21	0.06	3.15
Wushishi town	6.27	5.49	126	0.52	1.29	2.23	0.18	0.08	2.82
Tunga kawo	6.73	5.61	114	0.46	1.2	2.09	0.24	0.16	2.6
Bankogi	7.84	6.76	77	0.85	2.49	4.28	0.22	0.05	3
Maito	7.65	6.48	108	0.33	0.69	1.2	0.16	0.09	2.75
Tsohon dabiri	6.47	5.62	133	0.36	0.92	1.58	0.19	0.07	2.5

Landuse Classification of the study for 30 years (1992-2022)

Wushishi is a rural and agerian area which is experiencing different agricultural practices rigorous economic growth since the last two to three decades back. The increase in agricultural activities in the area has mount pressure that change the Land-use pattern. Three decade (1992-2022) Landsat imageries were analysis, various Landuse classification in the study area were identified. Land use/ land cover distribution by statistical from 1992-2002 as gotten from the image classifications in Figure 4.5 are presented in the Tables 10 and 11.

The estimation of Landuse analysis shown in Table 3 indicated that in 1992 the predominant Landuse is natural vegetation which accounted for 17417.96 hectares (47.14%) of the study area. Settlements occupied only 555.66 hectares (2.63%) while Farm land occupied 7865.11 hectares (38.81%); water body occupied 371.88541 (1.9%) and wetland occupied 2292.76 hectares (11.12%). This shows that at this period, the inhabitants of the study area were very small in number and their occupation then was farming and hunting and other primary activities. The year 2012 analysis revealed that farming activities in the area increase from 37.12% in 1999 to 48.9% in 2022, Natural vegetation decrease from 47.14 in 1999 to 32.76 in 2022 (Figure 6).

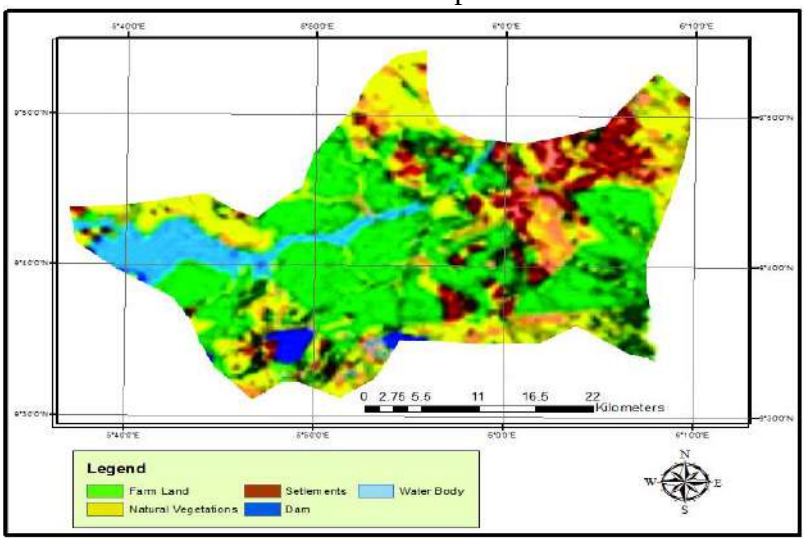

Figure 1: Landuse Classification of the study area in 2012

Table 5: Land Use/Land Cover in 2012

Land use	Area in Hectares	Percentage (%)
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Researcher's Analyses, 2020

Table 6: Land use/land cover in 2019

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Water body	4193.078175	1.9
Total	20267.00	100

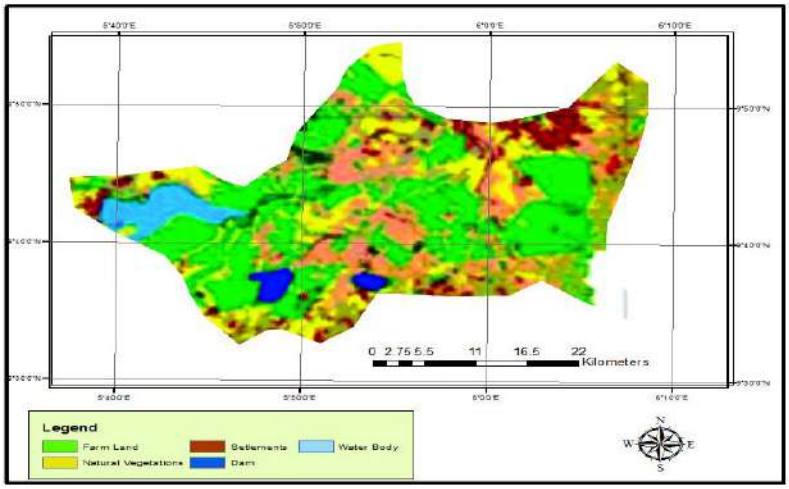

Figure 2: Landuse Classification of the study area in 2019

The analysis of the study area in 2021 is shown in Figure 7, the statistics shown in Table 4.6 shows that natural vegetation has decreased to 12.15%, Farmland has increased from 48.9% to 65.2%, settlements also increased from 5.23% to 11.32%, water body remains as 1.9%.It was observed from the analysis in Figure 6 that, farmland has expanded from part of the western part of the study area to the northern part through the eastern part of the area, most of the natural vegetation in 1989 has been opened up for farming activities.

Table 7: Land use/land cover in 2022

Land use	Area in Hectares	Percentage (%)
Natural Vegetation	1193.078175	12.15
Wetland	7709.2272	9.43
Farm Land	7906.369125	65.2
Settlement	2552.008275	11.32
Water body	4193.078175	1.9
Total	20267.00	100

Researcher's Analyses, 2022.

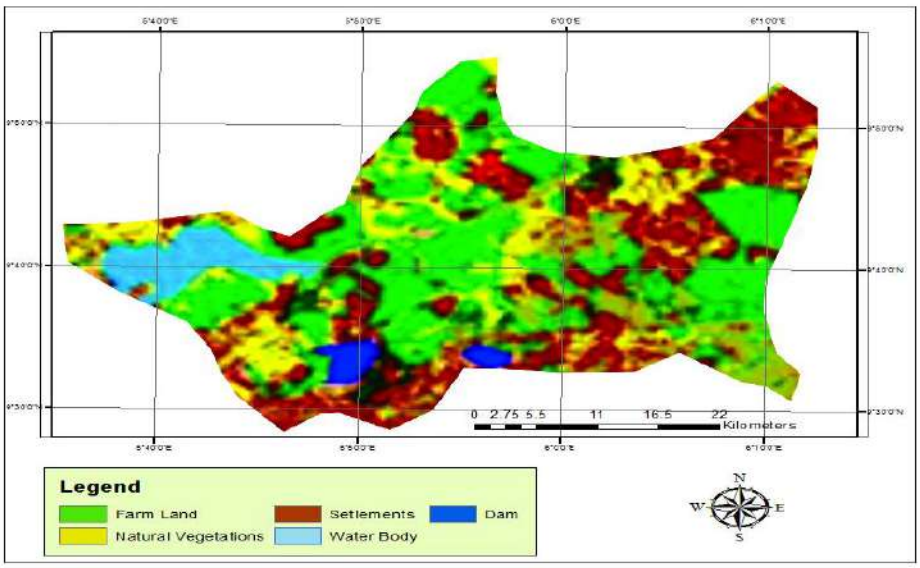

Figure 3: Landuse Classification of the study area in 2022

Distribution of Soil Potential Efficiency

High-resolution satellite detects soil moisture of a particular wetland with a sensitive multisensory lens. Soil moisture is basic in determining the infiltration process within a wetland catchment area. The incorporation of soil moisture data into the runoff prediction model highly influences estimations. Figure 8 shows the soil texture map of the study area.

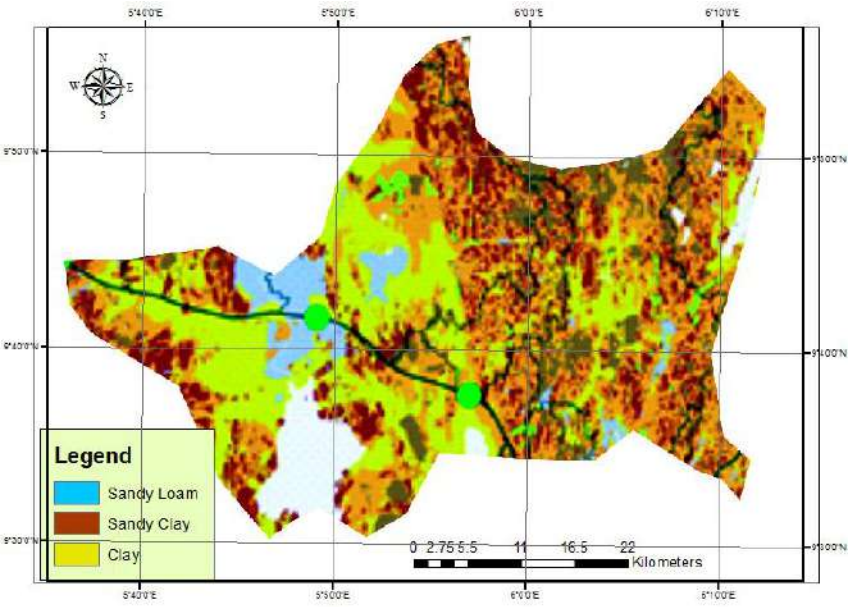

Figure 4: Soil Texture Map of the Study Area

Three major classes of soil were identified in the study area, these are sandy loam, sandy clay and clay soil (Figure 9). The use of remote sensing instead of the conventional method of measurement in estimating soil moisture content, which is capable of covering large surface areas within the shortest period with the accuracy of acquired data.

Variation in contents of the soil at different location using laboratory test

Analysis results of the soil content were computed at different locations in the study area, the parameter analysis were pH H_20, pH $CaCl_2$, Conductivity, %TON, %OM, Na coml/kg, K cmol/kg, and Ca cmol/kg. The analyses in Table 4.7 show the results of soil sample analysis. It shows that Bankogi has the highest pH. H_2O value of 7.84 follow by Maito with 7.65, Zungeru camp with 7.39 while Wushishi town has the lowest with 6.27. The soil pH of the study area ranged from 6.47 to 7.84 and was rated as "strongly acidic" to "moderately acidic" as per the soil pH classification by Tekalign and Tadesse (1991). The analysis showed a significant difference in soil parameters from h locations ($p < 0.01$) and soil depth ($p < 0.05$) while there were no differences due to interaction effect. Significantly higher was recorded in cultivated land and grazing lands. Nevertheless, no significant difference ($p > 0.05$) was observed in the parameters among land use type and soil depth.

Table 8: Characteristics of soils of sample locations in Niger State, Nigeria

Sample points	pH. H_2O	pH. $CaCl_2$	Condt	%TON	%TOC	%OM	Na cmol /kg	K cmol /kg	Ca cmol /kg
Zungeru Camp	7.39	6.55	84	0.38	0.98	1.68	0.21	0.06	3.15
Wushishi town	6.27	5.49	126	0.52	1.29	2.23	0.18	0.08	2.82
Tunga kawo	6.73	5.61	114	0.46	1.2	2.09	0.24	0.16	2.6
Bankogi	7.84	6.76	77	0.85	2.49	4.28	0.22	0.05	3
Maito	7.65	6.48	108	0.33	0.69	1.2	0.16	0.09	2.75
Tsohondabiri	6.47	5.62	133	0.36	0.92	1.58	0.19	0.07	2.5

Source: Author (2020)

The analysis further shows that Bankogi has the highest pH. CaCl2 of 6.76 follow by Zungeru Camp with 6.55 while Wushishi town still has the lowest value of pH. CaCl2 with 5.49. it was also discovered from the analysis that Tunga Kawo dam has the highest Nacmol value of 0.24 and Maito has the lowest with 0.16. Zungeru camp has the highest Cacmol value of 3.15 while Maito has the lowest with 2.5. The analysis signifies that soil samples in the area were varies from one site to the other. The physicochemical parameters of the soil were also analyzed based on the different locations in the area, the results shows variations in the parameter tested. It shows that Zungeru camp has the highest Mgcmol and Avail P, Wushishi, Tunga Kawo dam and Tsohon dabiri has the highest value of Exch A (0.06), Wushishi town has the highest percentage of sandy soil, Tunga-kawo dam has the highest clay while Zungeru camp has the highest silt (Table 8)

Table 9 : **Physiochemical properties**

Sample points	Mgcmol/kg	Avail P mg/kg	Exch A cmol/kg	CECcmol/kg	%Sand	%Clay	%Silt
Zungeru camp	1.22	4.14	0.04	15.36	52	12	36
Wushishi town	0.4	3.65	0.06	13.94	71	7	22
Tunga dam	0.34	4.3	0.06	16.17	59	17	24
Bankogi	0.85	6.22	0.04	14.55	64	9	27
Maito	0.65	2.85	0.04	16.83	60	10	30
Tsohon dabiri	0.8	3.4	0.06	13.75	66	12	22

Source: Author (2020)

The increase in clay content and a decrease in the sand and silt fractions in the lower soil layers could be attributed to the downward migration of clay particles in the soil profile as evidenced by its higher contents in Mgcmol/kgthat ranges between 0.8-1.22; %Sand ranges between 52-66; %Clay ranges between 9-17 and the selective removal of finer soil particles from surface soils by erosion leaving behind the coarser fractions. It was higher clay content in lower soil depths and forest land than the cultivated and grazing lands. The resemblance of this result to the works of these authors could be associated with the similarity in ecosystem and land management practices.

Map areas of potential wetland soils for agricultural practices using Remote sensing technique

From the soil sustainability potential map, it is noted that Farmers in the study area are subjected to limited dry days for spring fieldwork coupled with inadequate drainage that sustains the field operation for the next rainfall season.

From the study potential evapotranspiration and monthly rainfall are compared which shows rainfall is larger than potential evaporation during the rainy season indicating no need for practicing irrigation during the rainy season. However, irrigation may become necessary in case of an unexpected dry spell. Moreover, areas within the ranges of 85.1 to 97.0 are characterized by typical wetland properties due to the presence of lake and soil conditions that helped to retain water at high potential. The (NIR) over the growing period between 830 and 1630 mm/year (Figure 9). The lowland area was characterized by higher NIR when the temperature was high for the growing period.

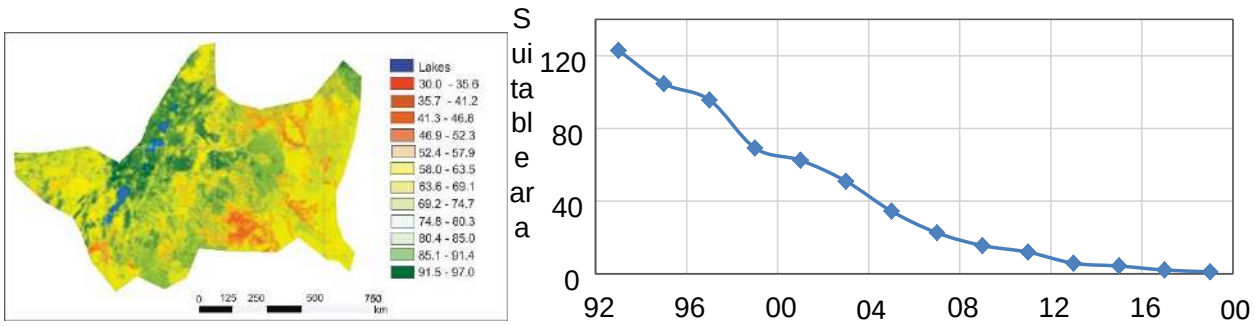

Figure 10: Suitable irrigation area at different suitability level

Analysis from River Basin Authority scale shows that the average fraction of irrigable area in Kanko, Tagwagi and TungaKawo ranges from 7.5 to 12.4% of the potential suitable land. Farmland has expanded from part of the western part of the study area to the northern part through the eastern part of the area, most of the natural vegetation in 1992 are open up for farming activities. Zungeru camp the highest Mgcmol and Avail P, Wushishi, Tunga kawo dam and Tsohon dabiri has the highest value of Exch A (0.06), Wushishi town the highest percentage of sandy soil, Tunga Kawo dam the highest clay while Zungeru camp has the highest silt. The potentiality and suitability for farm range from 58.0 – 97.0 while 3.0-57.9 were not suitable for any agricultural activities.

Plate 2: Typical nature of the irrigated site in the study area used for dry season farming

Plate 3: Nature of drainage caused by land degradation

The topographic setting of Bankogi area shows the steep-sloped area with much vegetation enable extensive irrigation farming take place in the area. Maito area is mostly cultivated by smallholder farmers. The removal of trees without sufficient reforestation has resulted in

degradation, habitat damage, biodiversity loss, and aridity. Overgrazing were discovered in part of Zungeru camp, farmers in this area were complaining bitterly about the activities of herdsmen grazing their animals in that areas thereby causing soil erosion as a result of exposure of top soil. The activities of the herdsmen in the area reduces the usefulness, productivity, and biodiversity of the land and is one cause of desertification and erosion. Overgrazing is also seen as a cause of the spread of invasive species of non-native plants and of weeds.

Plate 4: Deforestation for housing development and activities of herdsmen

CONCLUSION AND RECOMMENDATIONS

Three major classes of soil were identified in the study area, these are sandy loam, sandy clay and clay soil. Most of the northern and eastern part of the area are much suitable for agricultural activities. The soil pH of the study area ranges from 6.47 to 7.84 and was rated as “strongly acidic” to “moderately acidic”. It showed a significant difference in soil parameter from h locations ($p < 0.01$) and soil depth ($p < 0.05$) while there were no differences due to interaction effect. Significantly higher was recorded in cultivated land and grazing lands. Nevertheless, no significant difference ($p > 0.05$) was observed in the parameters among land use type and soil depth. Bankogi has the highest pH. CaCl2 of 6.76 follow by Zungeru Camp with 6.55 while Wushishi town still the lowest value of pH. CaCl2 with 5.49 was also discovered from the analysis that Tunga kawo dam has the highest Nacmol value of 0.24 and Maito the lowest with 0.16. Zungeru camp has the highest Cacmol value of 3.15 while Maito the lowest with 2.5.

Therefore wetland utilization opportunities require more planning and detailed design work than most community projects, due to a combination of numerous factors. These factors include, significant rock and bedrock in the area, anthropogenic surface water influences and interferences, potential contaminant issues in soils and sediment, urban storm water inputs and the potential for contaminated storm water, multiple landowners and the developed nature of watersheds, community expectations, landowner expectations, the municipal regulatory system and questions relating to jurisdiction and urban infrastructure including roads, buildings, sidewalks, railways, storm water infrastructure, businesses, energy such as power poles and electrical systems as well as underground utilities such as gas lines, sewer lines, water lines etc.

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INDICATOR SPECIES AND FLORAL PREFERENCE OF HONEYBEES IN YOBE STATE, NIGERIA: INFERENCE FROM MELISSOPALYNOLOGICAL AND BIODIVERSITY CONSERVATION PERSPECTIVES

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ABSTRACT

The honeybee is the most valuable insect on planet earth. This is not because of the value of its direct products as they represent only 0.5% of the total agricultural production, but because of the enormous benefits accruing from the cross pollination of plants. This cross pollination ensures the improved quality and quantity of produce, fruits and seeds, improved species of self-germinating plants and also maintain the eco-balance on earth. As a matter of urgency, plants foraged by honeybees must be conserved for continuity if honey production is to be sustained and one of the ways to determine these plants is through pollen analytical studies. The study investigated the species of plants that were utilized in the course of honey production, vegetational history, biogeographical origin of honey and taxa most preferred by *Apis mellifera* (honey bees) in Yobe State, Nigeria. Four samples of honey were sourced. Samples were treated using standard palynological procedures. Pollen grains counts and fine morphological studies were made at x40 and x100 magnification, respectively. Out of fifty-six pollen types belonging to twenty-eight plant families of apicultural importance most foraged by *Apis mellifera* encountered, one was identified to family level, forty-four to generic level, ten to species level, and one was unidentified. The identified species originated from numerous genera of trees, shrubs, grasses and herbs. Bade, Nangere, Damaturu, and Nguru localities had pollen grain counts of 9835, 10,329, 7868 and 8606, respectively. The predominant pollen types include those of *Borassus aethiopium, Sarcocephalus latifolius*, *Vitellaria paradoxa, Senegalia mellifera, Mangifera indica*, *Calotropis procera*, *Daniella oliveri*, *Balanite orbicularis*, *Combretum* spp., *Khaya senegalensis*, *Parkia biglobosa*, *Psidium guajava*, and *Syzygium guineense*. Indicators of Sudan savanna taxa: *Acacia mellifera*, *Adansonia digitata*, *Balanite orbicularis*, *Borassus aethiopium*, *Calotropis procera*, *Piliostigma thonningii*, *Vitellaria paradoxa*, *Senegalia mellifera*, and those from the plant family Poaceae were the highest pollen contributors (28.5 %) followed by human impact taxa (28.4 %). Pollen weight ranged from 0.40 - 0.45 g indicating that the honey samples were undiluted. The honey samples were all multi-floral, which affirmed that they were of good quality. The season of honey production was between the period of the dry season and to early rainy season (October-April). Pollen assemblages reflected the vegetation of the study area to be Sudanean savanna vegetation

type that is highly impacted by human activities. Adequate conservation of these indicator species is strongly recommended for health, safety, renewable natural resource availability and environmental sustainability.

Keywords: *Apis mellifera*, Floral preference, Honey, Pollen analysis, Vegetational history.

INTRODUCTION

The honey bees (*Apis mellifera var. adansonii*), the pollinators of plants the world over; play a crucial role for wild and cultivated plants, especially in the tropics where insect pollination is vital (Winfree, 2010; Ollerton *et al*., 2011). Some honey components, such as carbohydrates, water, traces of organic acids, enzymes, amino acids, and pigments, come from bees and plants, while others, such as pollen and wax, appear during honey maturation (Agwu and Okeke, 1997).

The *Apis mellifera var. adansonii* (African honey bee) is very defensive and unpredictable; darker and smaller; more energetic and aggressive; and also irritable during the hot hours and hates noise. It builds its nest in closed spaces but migrates (swarms) often and abandoned its nest (absconds) when disturbed. It produces more drones (male bees). It gathers food all the year round, produces large quantity of honey yields every year (Breadbear, 2009).

The bee is the most valuable insect on planet earth. This is not because of the value of its direct products as they represent only 0.5% of the total agricultural production, but because of the enormous benefits accruing from the cross pollination of plants. This cross pollination ensures the improved quality and quantity of produce, fruits and seeds, improved species of self-germinating plants and also maintain the eco-balance on earth (Sivaram, 1995).

Co-evolution and mutualism have been cited as examples of relationships between honeybees and flowering plants. Honeybees and flowering plants are mutually dependent; honeybees need flowering plants for food in the form of pollen and nectar, whereas plants need honeybees for pollination (Essien *et al*., 2023). Honey contains pollen grains which are collected by honeybees while foraging the flowers for nectar (Essien, 2020).

The flora of an area provides a good reflection of the major climatic regime of the area. The influence of climate on other components of the environment is so great that every other climatic zone has its own characteristic vegetation type (Ige, 2017). Essien (2019) reported that the vegetation of an area is an integral and basic component of the ecosystem that is sensitive to changes in the ecosystem. He therefore opined that vegetation changes are themselves a response to and a reflection of variation in one or more of the factors of the environment, particularly climate. Thus, a close correspondence exists between vegetation and the rest of the environment, particularly climate and soil.

As a matter of urgency, plants foraged by honeybees must be conserved for continuity if honey production is to be sustained and one of the ways to determine these plants is through pollen analytical studies (Kayode & Oyeyemi, 2014; Byrant, 2018; Adekanmbi & Ogundipe, 2019). A combination of the insect and wind pollinated taxa found in a honey gives a unique understanding of the particular geographical location where the honey was produced and the plant communities in that region. This could shed more light on the important plants foraged by honeybees (Essien *et al*., 2022a).

Findings from Neumann and Carreck, (2010) in Nnamani and Uguru (2013) revealed that the population of honeybee (*Apis mellifera* L.) has experienced serious decrease in Europe, North America and the world in general. These losses highlight the potential risks for our natural and agricultural biodiversity through lack of pollination, and the repercussions on food security and human nutrition (Ratnieks and Carreck, 2010).

It has been reported that lack of food and particularly scarcity of pollen, within intensively farmed agricultural landscapes and degraded environment as a result of human impacted activities have actually contributed to the loss of plant species which honey bees foraged for pollen and nectar sources. Other biotic factors such as availability of plant genetic resources and their ability of these plant species to blossom, compete for resources, fight against pathogens, parasites, predators, and abiotic factors such as climate and pollutants are all contributory factors to this decline (Gounari, 2006). Potts *et al*. (2010) opined that nutritional stress due to habitat loss also played an important role in the collapsed of honeybee colonies.

Due to the fact that honeybees are known to travel more than 3 km in search of their preferred forage sources, studying the pollen content in honey significantly aids in understanding the geographical, ecological, and botanical origins of honey. Knowledge of botanical source of honey is a prerequisite for beekeepers to undertake migratory beekeeping for increasing honey production and pollination. When determining the honey's commercial quality, characterization is crucial because the season of flowering and nectar production for the same species can vary depending on location (Zamarlicki, 1984).

Additionally, palynological investigations have been performed to determine single- and multiple-floral honeys (Seijo and Jato, 1998; Valencia-Barrera *et al*., 1994; 2000). Identification of honey sources in an ecological zone is important for commercial beekeeping with the goal of increasing honey production. Knowledge of honeybee plants and time of pollen and nectar flow greatly influence the brood rearing activity and the functioning of honeybee colonies and production of honey as well as other hive products (Sivaram, 1995; Ostrowsha, 1998).

Recently, there are evident cultural, agricultural, unscientific and uncontrolled practices threatening the flora of several part of Yobe State. The report of a comprehensive and elaborate palaeoecological studies in Yobe State, Nigeria is almost non-existing and has not been given in any published literatures. The objectives of this study, therefore, are to ascertain the species of plants that were utilized in the course of honey production, vegetational history and biogeographical origin of honey as well as the taxa most preferred by *Apis mellifera* (honey bees). Knowing that the bee plants could be used as the basis for legalized protection and propagation of bee plants and farms. Pollen analytical studies have been found useful in deciphering such plants.

MATERIALS AND METHODS

Study Area: Bade, Nangere, Damaturu and Nguru are localities within Yobe State, North Eastern Nigeria. Increased seasonality and irregularity of rainfall impose semi-arid condition on the study area. The harmattan season between December and January is basically influenced by the North-East Trade winds. It has mean annual temperature of between 25 and 38^{o}C. There is extensive area of seasonal swamps. The vegetation is

typically mixed Combretaceous woodland with *Vitellaria paradoxa*, *Acacia senegal*, *Acacia albida*, *Zizyphus* spp., *Adansonia digitata*, and *Piliostigma reticulatum* being the dominant trees. The common grasses in the zone, Aristida, *Brachiaria*, *Panicum*, *Chloris*, *Digitaria*, and *Eragrostis* are mostly short. Cultivation is intense and together with heavy grazing, bush burning and cutting for firewood/ charcoal, and browse, has contributed to extensive desertification in the study area.

Sample collection: Four honey samples were collected from vendors who sources from the wild at the study area between the months of September and December, 2022. The honey were extracted by pressing and squeezing the combs, filtered into a bottle through fine mesh-copper gauze to avoid introduction of debris. Once collected the samples were labelled and transported to the Laboratory, Department of Biology, Nigerian Army University Biu, for pollen analysis.

Determination of pH: Honey (10 g) was dissolved in 75 ml of distilled water in a beaker and vigorously mixed using a glass rod, pH electric meter was immersed in the honey and values were taken.

Honey colour: The Munsell Soil Color Chart was used.

Pollen analysis: Three basic procedures were followed; honey quantification/dilution, pollen extraction using acetolysis and microscopy. All procedures followed the recommendation and techniques reported in Erdtman (1969); Louveaux *et al*. (1978), and Agwu *et al*. (2013).

M**ounting and microscopic examination**: On a 25.4 mm x 76.2 mm (1"×3") slide 1 mm-1.2 mm thick, one drop of thoroughly shaken precipitates suspension was mounted and covered with 18mm x 18mm cover slip. To keep the precipitation from drying out, the mount was sealed off at the edges with colorless nail polish Counting was done using Olympus microscope at x400 magnification while detailed pollen morphological studies to aid identification was done using Leica microscope at x 1000 magnification. Reference slides, pollen atlas and photomicrographs (Sowunmi, 1978; 1995; Agwu and Akanbi, 1985; Agwu *et al*., 2013; Shubharani *et al*., 2013; Essien *et al*., 2022b; Essien *et al*. 2023) was used for identification.

Weight of pollen grains: Honey (50 ml) and beaker (71.65 g) was weighed using the weighing balance. The honey was diluted with 1000 ml of distilled water and the formular below was applied:

Weight of pollen x factor of 20 = weight of beaker/liter of honey samples.

Data analysis: Data generated from the study was presented in form of tables and/ or graphical representation (histogram). The classification for representation of pollen types followed was the one recommended by Louveaux *et al.* (1978) for expressing pollen grain frequencies: Very frequent (over 45%), frequent (16-45%), rare (3-15%) and sporadic (> 3%).

RESULTS AND DISCUSSIONS

Pollen Analysis Pollen analytical examination of honey samples from four localities in Yobe State, Nigeria was carried out to ascertain the different pollen types present in the honey samples, the botanical, ecological and geographical origin of the honey, the season of honey production in the study localities as well as the weight of the pollen grains which could be used to deduce between adulterated and pure honey and the

results revealed great diversity in size, shape, aperture and sculpturing of pollen grains.

A total of thirty-six thousand six hundred and thirty- eighty (36,638) pollen grains count were encountered. Result showed that out of fifty-six (56) pollen types belonging to twenty-eight (28) plant families documented, one (1) were identified to family level, forty-four (44) to generic level, ten (10) to species level, and one (1) were unidentified. After dilution, the colours of the honey samples were observed and ranged from light-brown, dark-brown, brown and light-brown and the result are presented in table 1. The weight of pollen grains for the samples ranged from 0.40 g to 0.45 g per 10 g of honey. The weight of the sediment recovered per sample and the colour of the honey after dilution are given in Table 1.

The identified species originated from numerous genera of trees, shrubs, grass, and herbs. Bade, Nangere, Damaturu, and Nguru localities had pollen grain counts of 9835, 10,329, 7868 and 8606 respectively. The predominant pollen types include those of *Borassus aethiopium*, *Sarcocephalus latifolius*, *Vitellaria paradoxa*, *Senegalia mellifera*, *Acacia mellifera*, *Calotropis procera*, *Daniella oliveri*, *Balanite orbicularis*, *Combretum* spp., *Khaya senegalensis*, *Parkia biglobosa*, *Psidium guajava*, and *Syzygium guineense*. Indicators of Sudan Savanna taxa: *Acacia melliferai*, *Adansonia digitata*, *Balanite orbicularis*, *Borassus aethiopium*, *Calotropis procera*, *Piliostigma thonningii*, Poaceae, *Senegalia mellifera*, *Vitellaria paradoxa* were the highest pollen contributors (%) followed by human impact taxa (%). The pollen weight was between 0.40-0.45 indicating that the honey samples were unadulterated. The honey samples were all multi-floral, which affirmed that they were of good quality

Figure 2 showed that the most abundant plant families in order of reducing percentage were Caesalpinaceae (19.92%), Mimosaceae and Papilionaceae (17.82%), Rubiaceae and Malvaceae (15.92%), Myrtaceae (14.67%), Meliaceae (10.63%), Anacardiaceae (5.98%)), Arecaceae (4.93%), Boraginaceae (3.75%), Euphorbiaceae (2.64%), and Sapotaceae (2.44%); while the least abundant were Caprifoliaceae and Loranthaceae (0.01%).

The classification recommended by Louveaux *et al.* (1970) for expressing pollen grains frequencies have been adopted: very frequent (over 45%), frequent (16-45%), rare (3-15%) and Sporadic (less than 3%). The pollen spectrum of the honey sample in percentage composition is presented in each of the Tables.

The highest number of pollen types (43) was recorded for Nguru, (37) for Nangere and (27) for Bade respectively, whereas Damaturu (26) had fewer pollen types. The detailed pollen count of each sample is presented in Table 2. All the plants identified were grouped into different phytoecological groups (Table 4). Indicators species of the Derived savanna taxa contributed **9,835** (24.4%), Guinea savanna taxa **10,329** (18.6 %), Sudan Savanna taxa **7,868** (28.5%) and **8,606** (28.4%) recorded for human impact taxa. The predominant indicators species are presented Table 4.

Table 1: Physical properties of the four honey samples studied

Localities	Colour of honey after dilution	Weight of honey collected (g)	Weight of pollen (g)	pH value	Weight of honey (gram/litre)
Bade	Dark-brown	10	0.44		1135
Nangere	Light-brown	10	0.40		1271
Damaturu	Brown	10	0.45		1126
Nguru	Light-brown	10	0.43		1253

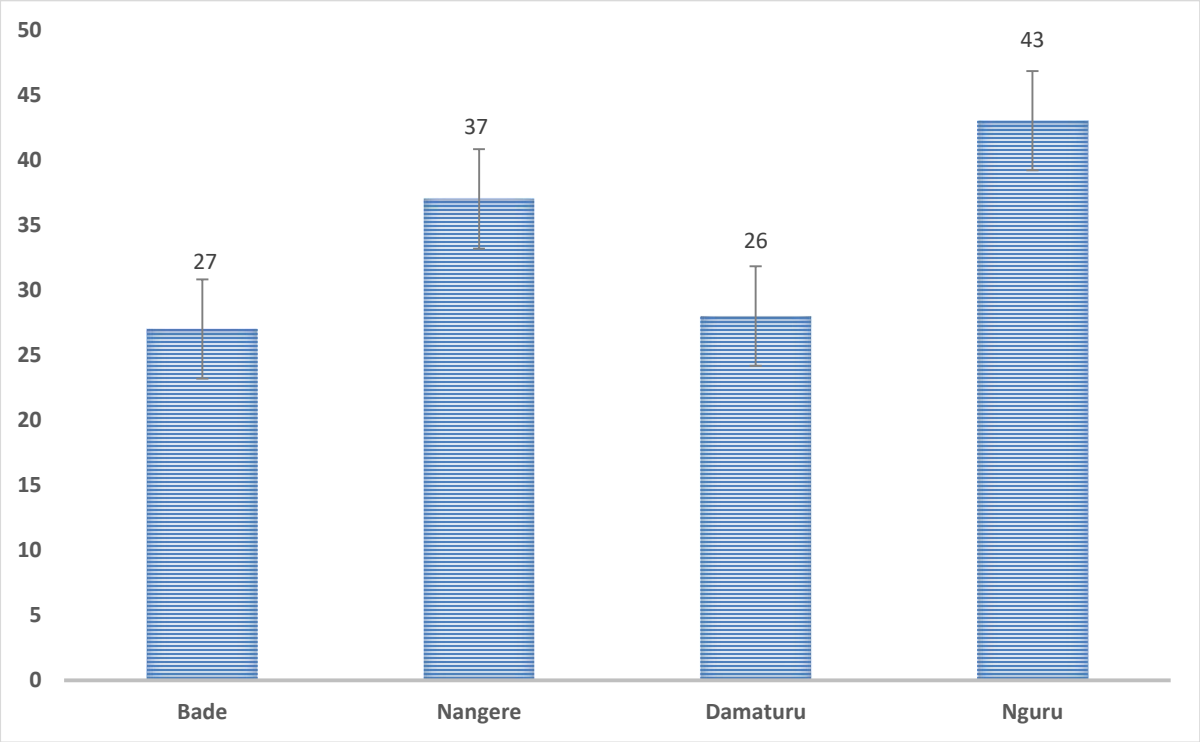

Figure 1: Histogram showing number of identified pollen types in the four honey samples from the study area clearly an indication of the high diversity of pollen types in Yobe State

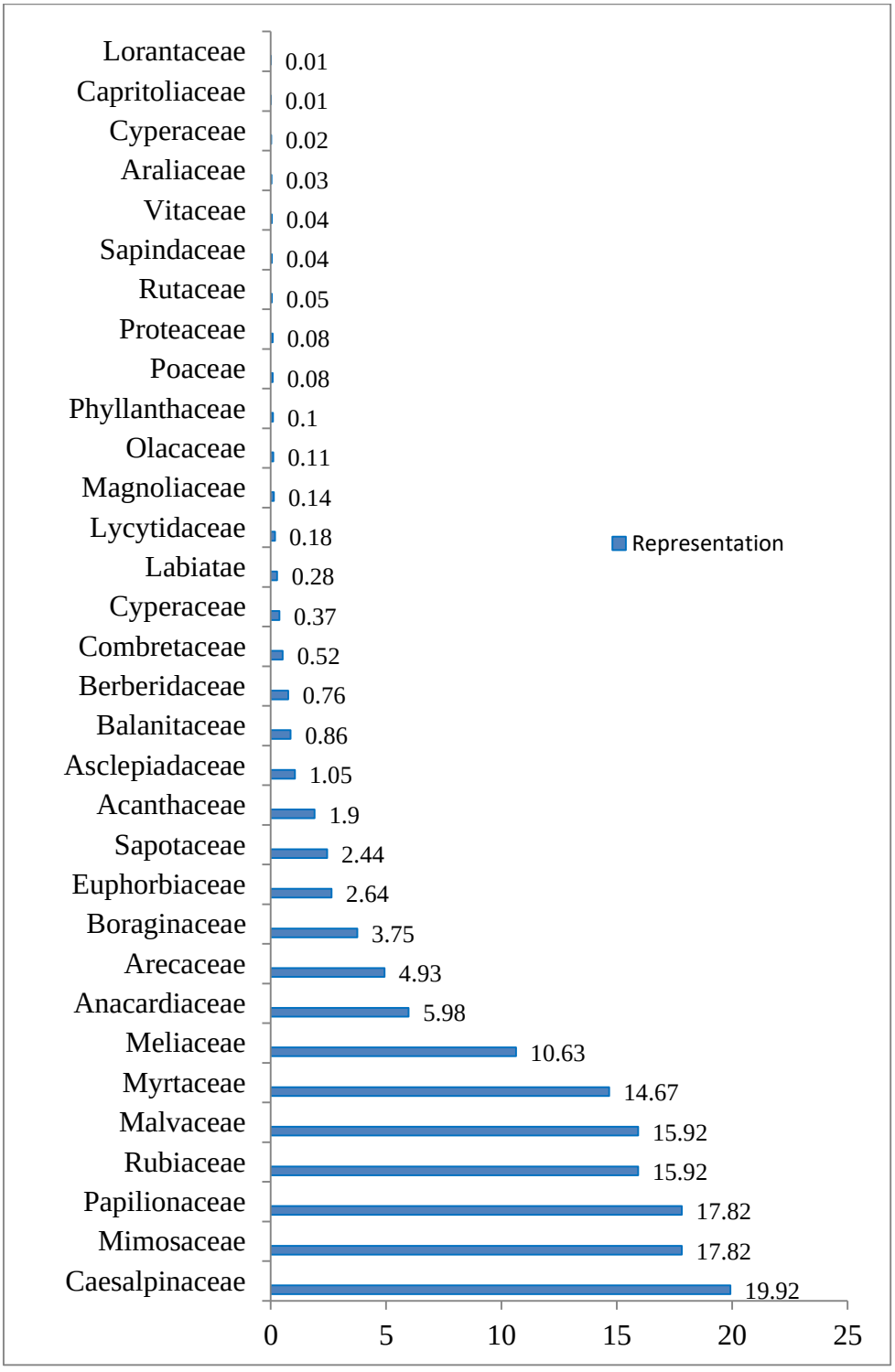

Figure 2: Relative abundance of the pollen types based on Plant family

Table 2: Absolute pollen counts/types recovered from recent honey samples in Yobe State, Nigeria

Pollen types/families	Localities in Shani									
	Bade	%	Nangere	%	Damaturu	%	Nguru	%	Total	%
1. ACANTHACEAE										
Strobilanthes spp.	289	2.9	483	4.7			43	0.5	815	2.2
2. ANACARDIACEAE										
Lannea acida	273	2.8	154	1.5					427	1.1
Mangifera indica	276	2.8	186	1.8	265	3.4			727	2.0
3. ARECACEAE										
Borassus aethiopium	432	4.4	145	1.4	237	3.0	532	6.1	1346	3.7
Hyphaene spp.	318	3.2							318	0.8
4. ASCLEPIADACEAE										
Calotropis procera	571	5.8	81	0.8	289	3.7	311	3.6	1252	3.4
5. BALANITACEAE										
Balanite orbicularis	692	7.0	235	2.3	183	2.3	199	2.3	1309	3.6
6. BERBERIDACEAE										
Mahonia oiwakensis					321	4.0			321	0.8
7. BORAGINACEAE										
Cordia africana			145	1.4	176	2.2	254	2.9	575	1.7
Cordia suckertii	412	4.2							412	1.1
8. CAESALPINACEAE										
Caesalpinia pulcherrima			23	0.2					23	0.06
Daniellia oliveri	251	2.6	556	5.3	265	3.3			1072	2.9
Piliostigma thonningii					163	2.0	240	2.8	403	1.0
Senegalia mellifera	324	3.3	467	4.5	87	1.1	541	6.3	1419	3.9
Senna alata	123	1.3			121	1.5			244	0.6
Senna occidentalis	445	4.5							445	1.2
9. COMBRETACEAE										
Combretum spp.			378	3.6	256	3.2	356	4.1	990	2.7
10. CYPERACEAE					312	3.9			312	0.8
Cyperus spp.			125	1.2			111	1.3	236	0.6
11. EUPHORBIACEAE										
Alchornea cordifolia	62	0.6			146	1.8	397	4.6	605	1.6
Euphorbia hirta			145	1.4	176	2.2	254	2.9	575	1.6
12. LABIATAE										
Leonotis nepetifolia							476	5.5	476	1.3
13. LYCYTIDACEAE										
Crateranthus letesturi	201	2.0	222	2.1	123	1.6	254	3.0	800	2.1
14. MALVACEAE										
Abutilon mauritanum	148	1.5	167	1.6					315	0.8
Adansonia digitate	179	1.8			124	1.6	387	4.5	690	1.9
Sida acuta			328	3.2					328	0.9

15. MAGNOLIACEAE										
Magnolia coco	124	1.3	274	2.6			164	1.9	562	1.5
16. MELIACEAE										
Azadirachta indica	240	2.4			197	2.5	232	2.7	669	1.8
Khaya senegalensis	236	2.4	544	5.2	120	1.5			900	2.4
Trichilia prieureana	231	2.3			159	2.0	121	1.4	511	1.4
17. MIMOSACEAE										
Acacia mellifera	190	1.9	578	5.6	480	6.1	376	4.4	1624	4.4
Acacia spp.			276	2.7	189	2.4	153	1.8	618	1.7
Albizia zygia			198	1.9	178	2.3	132	1.5	508	1.4
Parkia biglobosa	345	3.5	123	1.2	470	6.0	111	1.3	1049	2.9
Pentaclethra macrophylla	237	2.4	175	1.7			349	4.0	761	2.0
Prosopis africana	132	1.3	275	2.7					407	1.1
18. MYRTACEAE										
Eucalyptus spp.					146	1.9	592	6.9	738	2.0
Psidium guajava	428	4.6	271	2.6	364	4.6			1063	2.9
Syzygium guineense	412	4.2	387	3.7	587	7.5			1386	3.8
19. OLACACEAE										
Olax laxiflora	126	1.3	154	1.5			121	1.4	401	1.0
20. PAPILIONACEAE										
Bauhinia tomentosa					311	4.0			311	0.8
Canavalia virosa							239	2.8	239	0.6
Crotalaria spp.			245	2.4					245	0.6
Indigofera spp.			312	3.0					312	0.8
Milettia pinnata	468	4.7	199	1.9					667	1.8
21. PHYLLANTHACEAE										
Phyllantus spp.	165	1.7	420	4.0	133	1.7			718	2.0
22. POACEAE	164	1.7	109	1.0	195	2.5			468	1.3
23 PROTEACEAE										
Protea madiensis	131	1.3	298	2.9			232	2.7	661	1.8
24. RUBIACEAE										
Crossopteryx febrifuga	124	1.3	274	2.6			164	1.9	562	1.5
Morellia senegalensis					178	2.3	193	2.2	371	1.0
Mitragyna inermis	189	1.9					231	2.7	420	1.1
Sarcocephalus latifolius	387	3.9	274	2.6	587	7.5	412	4.8	1660	4.5
25. RUTACEAE										
Citrus spp.			468	4.5					468	1.3
26. SAPINDACEAE										
Allophyllus africanus			287	2.8	162	2.0	196	2.3	645	1.7
27. SAPOTACEAE										
Mimusops warneckei	234	2.4	159	1.5			121	1.4	514	1.4
Vitellaria paradoxa	276	2.8	189	1.8	153	1.9	112	1.3	730	2.0
28. INDETERMINATA					15	0.2			15	0.04
Total Pollen Counts	**9,835**	**100**	**10,329**	**100**	**7,868**	**100**	**8,606**	**100**	**36,638**	**100**

Table 3: Floral sources of the honey samples from the study area

Samples	Pollen type				Remark on floral origin	Pollen count / Category
	Very frequent (> 45%)	Frequent (16 – 45%)	Rare (3 – 15.9%)	Sporadic (< 3%)		
Bade	--	--	*Borassus aethiopium* (4.4), *Hyphaene* spp (3.0), *Calotropis procera* (5.8), *Balanite orbicularis* (7.0), *Cordia suckertii* (4.2), *Senegalia mellifera* (3.3), *Senna occidentalis* (4.5), *Parkia biglobosa* (3.5), *Psidium guajava* (4.6), *Syzygium guineense* (4.2), *Milettia pinnata* (4.7), *Sarcocephalus latifolius* (3.9).	*Strobilanthes* spp. (2.9), *Lannea acida* (2.8), *Mangifera indica* (2.8), *Daniellia oliveri* (2.6), *Senna alata* (1.3), *Alchornea cordifolia* (0.6), *Crateranthus letesturi* (2.0), *Abutilon mauritanum* (1.5), *Adansonia digitate* (1.8), *Magnolia coco* (1.3), *Azadirachta indica* (2.4), *Khaya senegalensis* (2.4), *Trichilia prieureana* (2.3), *Acacia mellifera* (1.9), *Pentaclethra macrophylla* (2.4), *Prosopis Africana* (1.3), *Olax laxiflora* (1.3), *Phyllantus* spp. (1.7), *Poaceae* (1.7), *Protea madiensis* (1.3), *Crossopteryx febrifuga* (1.3), *Mitragyna inermis* (1.9), *Mimusops warnecke* (2.4), *Vitellaria paradoxa* (2.8).	Multifloral	**9,835/ I**
Nangere	--	--	*Strobilanthes* spp. (4.7), *Daniellia oliveri* (5.3), *Senegalia mellifera* (4.5), *Combretum* spp. (3.6), *Sida acuta* (3.2), *Khaya senegalensis* (5.2), *Acacia mellifera* (5.6), *Syzygium guineense* (3.7), *Indigofera* spp. (3.0),	*Lannea acida* (1.5), *Mangifera indica* (1.8), *Borassus aethiopium* (1.4), *Calotropis procera* (0.8), *Balanite orbicularis* (2.3) *Cordia africana* (1.4), *Caesalpinia pulcherrima* (0.2), *Cyperus* spp.	Multifloral	**10,329/ I**

			Phyllantus spp. (4.0), *Citrus* spp. (4.5).	(1.2), *Euphorbia hirta* (1.4), *Crateranthus letesturi* (2.1), *Magnolia coco* (2.6), *Acacia* spp. (2.7), *Albizia zygia* (1.9), *Parkia biglobosa* (1.2), *Pentaclethra macrophylla* (1.7), *Prosopis africana* (2.7), *Psidium guajava* (2.6), *Olax laxiflora* (1.5), *Crotalaria* spp. (2.4), *Milettia pinnata* (1.9), Poaceae (1.0), *Protea madiensis* (2.9), *Crossopteryx febrifuga* (2.6), *Sarcocephalus latifolius* (2.6), *Allophyllus africanus* (2.8), *Mimusops warneckei* (1.5), *Vitellaria paradoxa* (1.8).		
Damaturu	--	--	*Mangifera indica* (3.4), *Borassus aethiopium*(3.0), *Calotropis procera*(3.7), *Mahonia oiwakensis*(4.0), *Daniellia oliveri*(3.3), *Combretum* spp.(3.2), *Cyperus* spp.(3.9), *Acacia mellifera*(6.1), *Parkia biglobosa*(6.0), *Psidium guajava*(4.6), *Syzygium guineense*(7.5), *Bauhinia tomentosa*(4.0), *Sarcocephalus latifolius*(7.5).	*Balanite orbicularis* (2.3), *Cordia africana* (2.2), *Piliostigma thonningii* (2.0), *Senegalia mellifera* (1.1), *Senna alata* (1.5), *Alchornea cordifolia* (1.8), *Euphorbia hirta*(2.2), *Crateranthus letesturi*(1.6), *Adansonia digitate*(1.6), *Azadirachta indica*(2.5),*Khaya senegalensis*(1.5), *Trichilia prieureana*(2.0), *Acacia* spp.(2.4), *Albizia zygia*(2.3), *Eucalyptus* spp.(1.9), *Phyllantus* spp.(1.7), *Poaceae*(2.5), *Morellia senegalensis*(2.3),	Multifloral	**7,868/ I**

				Allophyllus africanus(2.0) *Vitellaria paradoxa*(1.9).		
Nguru	--	--	*Borassus aethiopium*(6.1), *Calotropis procera(3.6),Senegalia mellifera*(6.3),*Combretum* spp.(4.1), *Alchornea cordifolia*(4.6), *Leonotis nepetifolia*(5.5), *Crateranthus letesturi*(3.0), *Adansonia digitate*(4.5), *Acacia mellifera*(4.4), *Pentaclethra macrophylla*(4.0), *Eucalyptus* spp.(6.9), *Sarcocephalus latifolius*(4.8).	*Strobilanthes* spp.(0.5), *Balanite orbicularis*(2.3), *Cordia africana*(2.9), *Piliostigma thonningii*(2.8), *Cyperus* spp.(1.3), *Euphorbia hirta*(2.9), *Magnolia coco*(1.9), *Azadirachta indica*(2.7), *Trichilia prieureana*(1.4), *Acacia mellifera*(1.8), *Albizia zygia*(1.5), *Parkia biglobosa*, , *Olax laxiflora*(1.4)**,** *Canavalia virosa*(2.8), *Protea madiensis*(2.7), *Crossopteryx febrifuga*(1.9), *Morellia senegalensis*(2.2), *Mitragyna inermis*(2.7), *Allophyllus africanus*(2.3), *Mimusops warneckei*(1.4), *Vitellaria paradoxa*(1.3).	Multifloral	**8,606/ I**

***Floral origin:** selected based on most represented (very frequently and frequently occurring) plant species

Categories: I (<20,000), II (20,000 – 100,000), III (100,000 – 500,000), IV (500,000 – 1,000,000) and V (>1,000

Table 4: Vegetation inference from pollen types recovered from honeys from the study area

Palaeoecological data		Vegetation type represented from absolute pollen counts				
		Derived savanna	**Guinea savanna**	**Sudan savanna**	**Human act taxa**	**Suggestive inference on biogeographical origin of honey**
Selected pollen types		*Alchornea cordifolia, Allophyllus africanus, Crossopteryx febrifuga,, Daniella oliveri, Milettia pinnata, Mimusops warneckei, Morelia senegalensis, Parkia biglobosa, Mahonia oiwakensis, Crateranthus letesturi, Pentaclethra macrophylla, Phyllanthus* spp., *Senna occidentalis*	*Lannea acida, Albizia zygia, Combretum* spp., *Prosopis africana, Sarcocephalus latifolius Senna alata,, Syzygium guineense, Trichilia prieureana, Khaya senegalensis, Cyperus* spp.	*Piliostigma thonningii, Vitellaria paradoxa, Acacia mellifera, Acacia* spp., *Adansonia digitata, Senegalia mellifera, Calotropis prosera, Cordia africana, Cordia suckertii, Hyphaene* spp., *Magnolia coco,* Poaceae, *Protea madiensis, Balanite orbicularis, Borassus aethiopium, Strobilanthes* spp.,	*Euphorbia hirta, Psidium guajava, Mangifera indica, Mitragyna inermis, Canavalia virosa, Crotalaria* spp. *Indigofera* spp., *Sida acuta, Azadirachta indica, Citrus* spp., *Caesalpinia pulcherrima, Bauhinia tomentosa, Eucalyptus* spp., *Abutilon mauritianum, Leonotis nepetifolia,*	
Total pollen count		**9,835**	**10,329**	**7,868**	**8,606**	
Localities	Bade (%)	40.65	30.60	17.52	26.20	-Sudan savanna/ Human impact

	Nangere (%)	24.95	41.48	19.17	27.56	-Sudan savanna/ Human impact
	Damaturu (%)	14.17	16.40	18.09	21.70	-Sudan savanna/ Human impact
	Nguru (%)	20.23	11.52	45.25	24.54	-Sudan savanna/ Human impact
Total pollen indicator of the vegetation (%) of Yobe State		**24.4**	**18.6**	**28.5**	**28.4**	**Yobe State is largely Sudan savanna that is highly impacted by human activities.**

Total pollen count = 36,638

Vegetation history and biogeographical origin of honey: The determination of a biogeographical origin of honey is based on the entire spectrum being consistent within the flora of that particular region (Louveaux *et al.*, 1978). The abundance of *Acacia mellifera*, *Acacia* spp., *Adansonia digitata*, *Balanite orbicularis*, *Borassus aethiopium*, *Calotropis procera*, *Combretum* spp., *Cordia africana*, *Daniella oliveri*, *Parkia biglobosa*, *Sarcocephalus latifolius*, *Piliostigma thonningii*, Poaceae, *Senegalia mellifera*, and *Vitellaria paradoxa* reflects the vegetation of Sudan Savanna. The occurrence of the pollen of the above listed plants in the pollen spectrum of the studied samples confirms their biogeographical origin reflecting Sudan savanna ecovegetation type that is anthropogenically disturbed. Similar findings on other vegetation zones were reported by Agwu and Okeke (1997); Essien *et al*. (2022c), Essien *et al*. (2023) as well as Essien and Olaniyi (2023).

According to pollen analysis of these honey samples, Sudan Savanna taxa were the highest pollen contributor (28.5 %) followed by Human Impact taxa (28.4%). The suggestive vegetational inference inferred from this honey pollen analysis revealed that the vegetation of Yobe State is largely Sudan Savanna highly impacted by human activities. Similar findings were reported by Essien *et al*. (2023) who opined that the plant *Senegalia mellifera* whose pollen grains are present in the pollen assemblage of the honey samples studied is used as fencing, livestock feed and building material for huts. The wood is prized also for fuel and making charcoal. All these are predominant indigenous occupations/ cultural lifestyle and heritage of the inhabitant of the study area.

The pollen analysis shows a fairly similar floral composition for the entire honey samples studied which is in line with the work of Sowunmi (1976) in Southeastern Nigeria and the high floral diversity of the forested-savanna ecozone by Agwu *et al*. (2013) in Northcentral Nigeria. The percentage of human impact indicator species could be attributed to anthropogenic activities in this region such as the activities of herdsmen (livestock grazing, annual bush burning, etc.),

deforestation, urbanization, and agricultural activities in line with Essien *et al*. (2022a) reports. From Table 4, there were clear indications that the study regions of Yobe State are largely Sudan Savanna highly impacted by human activities with little variation with respect to the different study localities.

Season of honey production: Most plants flower during the dry seasons, allowing honeybees graze during those times. For instance, the flowers of *Senegalia mellifera* are sources of nectar for honey-producing bees. To produce honey in the study area efficiently, this study examined the numerous pollen types and their distinct flowering seasons. According to Dalziel (1937) and Keay (1959) studies, flowering seasons differ for different plants. For example, *Mangifera indica* (February-May), *Morellia senegalensis* (November to January; March to April), *Mimusops warneckei* (April to June), *Alchornea cordifolia* (October to November; June - August), *Bombax buonopozense* (January to March), *Brachystegia eurycoma* (April to May), *Daniella oliveri* (November to January; March to April), *Delonix regia* (April to August), *Elaeis guineensis* (October-April), *Parkia biglobosa* (December to April), *Paullinia pinnata* December to January), *Trichilia prieureana* (January to March), *Tridax procumbens* (June to September), *Vitellaria paradoxa* (April to June). According to Sowunmi (1976) and Agwu and Akanbi (1985), *Parkia biglobosa*, and *Phyllanthus* spp. all have flowering periods between January and October. These flowering seasons can be used by beekeepers to maximize the production of honey in the study area.

Floral preference of honeybees (*Apis mellifera* var. *adansonii*): Pollen analysis of honey samples examined indicates the presence of pollen types of different plants species, most likely a reflection of more species diversity characteristics of Human impacted Sudanean Savanna vegetation type. The determination of the floral origin of honey is based on the relative frequencies of pollen types of various nectar producing plants species in the honey samples. Generally entomophilous plants were observed to be more abundant in the pollen spectrum of each honey sample studied and the honey from the source localities were rich in pollen types.

In terms of floral sources, this study revealed that all the honey samples were multifloral (Table 3); suggesting that honeybees (*Apis mellifera* var. *adansonii*) produced honey by gathering a variety of pollen and nectar that they found to be most appealing. According to Agwu *et al*. (2013), Kayode and Oyeyemi (2014), Adeonipekun *et al*. (2016), Adekanmbi & Ogundipe (2009), and Essien *et al*. (2022c), the majority of Nigerian honeys fall into the type I description of Parades and Bryant (2019). The pollen types from the least abundant families may not have been fully domesticated, or their pollen does not rank among the top choices for honeybees.

Based on the relative frequencies of the various pollen types from nectariferous and polleniferous species in the honey samples, the botanical origin of the honey is identified. The predominance of plant families like the Caesalpinaceae, Mimosaceae, Papilionaceae, Rubiaceae, Malvaceae, Myrtaceae, Meliaceae, Anacardiaceae and Arecaceae (Figure 2) has been reported in numerous other studies (Dukku, 2013; Kayode and Oyeyemi, 2014; Adekanmbi and Ogundipe, 2009), which is unmistakably a reflection of the importance of these families in honey The least numerous families might not have been fully domesticated or their pollen may not be favoured by honeybees over the most numerous families.

The study showed that all honey samples were multifloral (Table 3), implying that honeybees

(*Apis mellifera* var. *adansonii*) foraged for several preferred pollen and nectar sources to produce the honey. Agwu and Njokuocha (2004) reported that the differences which were observed in the number of contributing plant species in the honey samples may be attributed to the variation in edaphic factors, microclimate, lack of uniformity in the establishments of plants (including flowering period) and selective behaviors of bees during their foraging activities.

Originality of honey: Deciphering the botanical and/or ecological origin and the authenticity of honey samples from Yobe State, Nigeria was the focus of this study. Complimentarily, knowing the best times for apiculture by understanding the flowering seasons of the plant was another objective. Having seen evident impact of humans in the study location, pollen analytical study shed more light on the important bee plants that may require preservation for continuous supply of quality honey in Yobe State. The study found that all honey samples were acidic in nature (Table 1) and pollen weight revealed that the honey sample were not adulterated. Cases of honey adulteration have been reported in many cities in Nigeria. For example, Agwu *et al*. (2013) from Dekina; Aina *et al*. (2014) from Kogi East; Anidiobu (2016) from Kabba; Essien *et al*. (2022a) from Ijumu has been reported to be good. This study confirms those from Yobe State; that were randomly sampled are also of good quality. Honey quality can be measured by its pollen diversity and count (Ige and Modupe, 2010; Oyeyemi, 2017; Essien *et al*., 2022c). The high diversity of pollen types (Figure 1) further supports the originality of the honey samples (Bogdanov and Martin, 2002).

CONCLUSION

Pollen analysis is still an indispensable method for the determination of vegetational history and biogeographical origin of honey; major season of honey production; floral preference of honey bees, and purity status of honey based on its floral and geographical origin. It can to some extent, reflect the floristic characteristics of the area the honey was collected from. This study has revealed some important indicator species of vegetation types in Yobe State as well as honey bees (*Apis mellifera* var. *adansonii*) preferred pollen and nectar sources. These plants include those of *Borassus aethiopium*, *Sarcocephalus latifolius*, *Vitellaria paradoxa*, *Senegalia mellifera*, *Mangifera indica*, *Calotropis procera*, *Daniella oliveri*, *Balanite orbicularis*, *Combretum* spp., *Khaya senegalensis*, *Parkia biglobosa*, *Psidium guajava*, and *Syzygium guineense*. Among others. The present study revealed that indicator species of Sudan savanna taxa documented in these study are worthy of conservation and their sustainable exploitation managed in the apiculture to enhance large scale production of honey in Yobe State, Nigeria. The study further revealed that the vegetation of Yobe State is largely Sudan Savanna type and is currently being impacted by human activities of subsistence.

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CHECKLISTS OF MEDICINAL PLANTS USED FOR TREATING SNAKEBITES AND SOCIO-ECONOMIC CHARACTERISTICS OF ENVENOMATION HERBALISTS IN NORTHEASTERN NIGERIA

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ABSTRACT

A survey was carried out in northeastern Nigeria by sampling three states: Bauchi, Gombe and Borno. Questionnaire and interview were used to collect data from 63 snakebite envenomation herbalists through purposive and snow balling sampling methods. Seventy two medicinal plants were mentioned that are being used for treating snakebites. The five most used are *Crinum asiaticum* (Hausa name: Bakin gadali; English name: Spider lily), *Annona senegalensis* (Hausa name: Gwadon daji; English name: Sweetsop), *Parkia biglobosa* (Hausa name: Dorawa; English name: African locust beans), *Aleurites moluccana* (Hausa name: Kukuki; English name: Candle berry) and *Cassia singueana* (Hausa name: Rumfu English; name: Winter flowering senn). The envenomation herbalists' socio-economic characteristics indicated that 84.13% are males; 90.48% are married; 36.51 % are within 20 to 40 years of age; 50.79% are within 41 to 60 years while others are above 60 years; 16.92% are solely herbalists while others are engaged in different occupations which include farming, animal rearing, civil service and business; 23.81% have experience of 16 – 20 years in treating snakebites envenomation and are dominants while 9.52% have 5 – 10 years with 17.46% having over 35 years of experience; 61.90% have their daily income above N3000. In terms of levels of education: 22.22% had informal education while others had formal education with dominantly 30.16% having basic education while1.59% had postgraduate qualifications. The northeastern zone of Nigeria has great plant and human resources for sustainably developing treatment of snakebites envenomation using medicinal plants, and there is a need for a similar survey nationally.

Keywords: Snakebites, Envenomation Herbalist, Medicinal Plants, Ethnomedicine, Public health

INTRODUCTION

The World Health Organization (WHO) recently labeled snakebite a neglected tropical illness and a global health priority. Each year, snakebites are thought to cause 2.5 million envenomation, 138,000 fatalities, and over 500,000 cases of permanent disability globally (Benjamin *et al*., 2020). The continents of Asia and Sub-Saharan Africa are thought to have the highest rates of snakebites (Yirgu & Chippaux, 2019). Snakebite is an injury that occurs when you are bitten by a snake (Carmelita, 2022). Snakebite is a bite from a poisonous snake, such as a coral snake, cottonmouth, copperhead, rattlesnake, or rattler. These snake bites should be treated as medical emergencies (Melisa, 2021).

In many tropical and subtropical nations, snakebite is a neglected public health problem. Each year, there are roughly 5.4 million snakebites, resulting in 1.8 to 2.7 million cases of envenoming (poisoning from snakebite). Every year, there are between 81,410 and 137,880 fatalities, as well as around three times as many

amputations and other forms of lifelong disability (WHO, 2021)

Owing to their safety, efficacy, cultural preferences, affordability, abundance, and availability, plants have been used to treat medical issues since antiquity and are becoming more relevant in the current period (Eshete & Molla, 2021). Snakebites are still a severe issue in Nigeria, especially in rural regions where access to quick, efficient treatment is scarce (Nodza et al., 2020). This research's objective is to conduct an ethnobotanical survey of plants used as remedy for snakebites and socio-economic characteristics of the envenomation herbalists in North Eastern Nigeria.

MATERIALS AND METHOD

Study Area

The area of the study will be North-East, Nigeria. One of Nigeria's six geopolitical zones, the North-East represents both the geographical and political heartland of the nation. The six states that make up this region are Adamawa, Bauchi, Borno, Gombe, Taraba, and Yobe. With roughly a third of Nigeria's total size, the North-East is the country's largest geopolitical region. About 12% of the nation's population, or around 26 million people, live in the region. The region's two most populated cities are Maiduguri and Bauchi. North eastern Nigeria shares land borders with Cameroon, Chad, and Niger. The states' residents' occupations are primarily in agriculture and animal husbandry. Their food crops include cassava, yam, guinea corn, maize, millet, and rice, while their cash crops are typically cotton and groundnut (Stoddard *et al.*, 2020).

Data Collection

Questionnaire and interview were the fact finding techniques used in this research. And purposive and snowballing sample techniques will be adopted for this research. Therefore, three of the states in North-eastern zone Nigeria (Bauchi, Gombe and Borno) were surveyed and data were obtained.

Data Analysis

The data collected were analysed using descriptive statistics such as frequency, percentage and ranking.

RESULTS AND DISCUSSION

Out of the 72 plants (Table1) which the herbalists (respondents) revealed to be using in treating snakebites *Crinum asiaticum* was most mentioned in all the locations where the survey was conducted, hence may be commonly available and very effective in treatment of snakebite envenomation. The plants comprise grasses, shrubs and trees; different parts are used (roots, stems, stem barks and leaves).

Table 1: Medicinal Plants used for treating Snakebites in North-eastern Nigeria

S/No.	Hausa Name	English/ Common Name	Scientific Name	Family Name	Bauchi	Gombe	Borno	Total	Ranking
1.	Bakin gadali	Spider lily	*Crinum asiaticum*	Amaryllidaceae	9	6	5	20	1st
2.	Gwadon daji	Sweetsop	*Annona senegalensis*	Annonaceae	6	5	1	12	2nd
3.	Dorawa	African locust beans	*Parkia biglobosa*	Fabaceae	2	1	3	6	3rd
4.	Kukuki	Candle berry	*Aleurites moluccana*	Euphorbiaceae	1	2	3	6	3rd
5.	Rumfu	Winter flowering senn	*Cassia singueana*	Fabaceae	2	-	2	5	5th
6.	Kargo	Monkey bread	*Pilosigna thonningii*	Fabaceae	2	-	2	4	6th
7.	Kuka	Baobab	*Adansonia digitate*	Malvaceae	1	3	-	4	6th
8.	Ararrabi	Frankincense tree	*Boswellia dalzielii*	Burseraceae	1	3	-	4	6th
9.	Doman dutsi	Calabash tree	*Crescentia cyete*	Bignoniaceae	3	-	-	3	9th
10.	Bini da zugu	Barbadose nut	*Jatropha curcus*	Euphorbiaceae	1	2	-	3	9th
11.	Maje	Balsam tree	*Daniellia oliveri*	Fabaceae	1	1	1	3	9th
12.	Yazawa	Cashew	*Anarcadium occidental*	Anacardiaceae	2	-	1	3	9th
13.	Sanya	Violet tree	*Securdaca longipedunculata*	Polygalaceae	-	3	-	3	9th
14.	Farun biri	Lan	*Lannea schimperi*	Anacardiacea	-	-	3	3	9th
15.	Namijin goro	Bitter kola	*Garcinia kola*	Clusiaceae	1	1	-	2	15th
16.	Mangwaro	Mango	*Magnifera indica*	Anacardiaceae	2	-	-	2	15th
17.	Hankufa	Sleepy morning	*Waltheria indica*	Malvaceae	1	-	-	1	27th
18.	Marke	African bitch	*Anogeissus leiocarpus*	Combrtaceae	1	-	1	2	15th
19.	Tokar gona	Blue pussyleaf	*Nelsonia canscenes*	Acanthaceae	1	-	1	2	15th
20.	Turgunuwa	Jute mallow	*Coechurs olitorious*	Tiliceae	1	-	1	2	15th
21.	Rai-daure	Coffee senna	*Cassia occendatalis*	Caesepinaceae	-	2	-	2	15th
22.	Shibrah	Pearl millet	*Pennisetum glaucum*	Poaceae	-	2	-	2	15th
23.	Tsamiya	Tamarind	*Tamarindus indica*	Fabaceae	-	1	1	2	15th
24.	Tumfafiya	Sodom apple	*Calotropis procera*	Asdepiadaceae	-	2	-	2	15th
25.	Albasa	Onion	*Allum cepa*	Amaryllidaceae	-	1	1	2	15th
26.	Gamji	Flake rubber tree	*Ficus platyphylla*	Moraceae	-	-	2	2	15th
27.	Kumbar shaho	White thorn	*Acacia polyacantha*	Fabaceae	1	-	-	1	27th
28.	Cikara				1	-	-	1	27th
29.	Aduruku	Tree of life	*Fiscus plathyphylla*	Moraceae	-	-	2	2	15th
30.	Alobera	Aloe vera	*Aloe barbadensis*	Liliceae	1	-	-	1	27th
31.	Baska	Aponge gourd	*Luffa aegytiaca*	Cucurbiceae	1	-	-	1	27th

32.	Gawo	Winther thorn	*Acacia albida*	Fabaceae	1	-	-	1	27th
33.	Farar kaya	Shittim wood	*Acacia seyal*	Fabaceae	1	-	-	1	27th
34.	Tafasa	Desert senna	*Senna covesi*	Fabaceae	1	-	-	1	27th
35.	Aduwa	Desert date	*Balanites aegypiaca*	Zygophyllacea	1	-	-	1	27th
36.	Sabara	Senegal tea plant	*Guiera senegalensis*	Combretaceae	1	-	-	1	27th
37.	Zamarke/ Maza tsaye	Kat sola	*Aeschynomene indica*	Fabaceae	1	-	-	1	27th
38.	Gadali	Harmattan lilly	*Crinum jagus*	Amaryllidaceae	1	-	-	1	27th
39.	Harshantin kiya	Protea	*Protea ellioti*	Proteaceae	1	-	-	1	27th
40.	Munjirya	Coral tree	*Erythria senegalensis*	Fabaceae	1	-	-	1	27th
41.	Bishiyar janyaro	Chicken blood	*Spatholobus suberectus*	Fabaceae	1	-	-	1	27th
42.	Hannu biyar	Barbasco	*Paullini apinata*	Sapindaceae	1	-	-	1	27th
43.	Kalan wuka	Wild flower	*Aspilia Africana*	Asteraceae	1	-	-	1	27th
44.	Bakin bunu		*Indigofera pulchra*	Fabaceae	1	-	-	1	27th
45.	Icen baushe	Horse may	*Ulmus minor*	Ulmaceae	1	-	-	1	27th
46.	Gwanda	Paw-paw	*Carica papaya*	Caricaceaea	1	-	-	1	27th
47.	Albiziya	Fry wood	*Albizia lebect*	Fabaceae	1	-	-	1	27th
48.	Dashi/iskici	African myrrh	*Commiphorra Africana*	Burseraceae	1	-	-	1	27th
49.	Tafarnuwa	Garlic	*Allium sativum*	Amaryllidaceae	1	-	-	1	27th
50.	Farar Tauraruwa	Bush willow	*Combretum glutinosum*	Combretaceae	1	-	-	1	27th
51.	Karan masarachi	Resurrection plan/life	*Bryophyllum pinnatum*	Crassulaceae	-	1	-	1	27th
52.	Baure	Sycamore fig	*Ficus sycomurus*	Moraceae	-	1	-	1	27th
53.	Masara	Corn	*Zea mays*	Poaceae	-	1	-	1	27th
54.	Zogale	Drumstick	*Moringa oleifera*	Moringaceae	-	1	-	1	27th
55.	Faskara tuhi	Creeping thustle	*Cirsium arvenses*	Asteraceae	-	1	-	1	27th
56.	Taura	Tallow tree	*Deuterium microcarpum*	Fabaceae	-	1	-	1	27th
57.	Rogo	Cassava	*Manihot esculenta*	Euphorbiaceae	-	1	-	1	27th
58.	Sakayau	Sweet killer	*Anisopu mannii*	Apocynaceae	-	1	-	1	27th
59.	Morinda	Mulberry	*Morus alba*	Moraceae	-	1	-	1	27th
60.	Wake	Velvel beans	*Mucuna puriense*	Fabaceae	-	-	1	1	27th
61.	Tohon kaya	African ebony	*Diospros mespiliforms*	Ebenaceae	1	-	-	1	27th
62.	White lilly	White lilly	*Lilium candidum*	Liliaceae	-	-	1	1	27th
63.	Darbejiya	Neem	*Azadirachta indica*	Meliaceae	-	-	1	1	27th
64.	Gurjiya	Bambaranut	*Bombax costatum*	Bombaceae	-	-	1	1	27th
65.	Duhuwa	Flame thorn	*Acacia ataxacantha*	Fabaceae	-	-	1	1	
66.	Karan masarachi	Cathedral bells	*Bryophyllum pinnatum*	Crassulaceae	-	-	1	1	27th
67.	Nonon Kurciya	Ascending weedy	*Euphorbia hirta*	Euphorbiaceae	-	-	1	1	27th
68.	Katala	Walnuts/ Butternut	*Jugans cinerea*	Juglaridaceae	-	-	1	1	27th

69.	Takalmin Makka	Cactus plant		Cactaceae	-	-	1	1	27th
70.	Wada	Poison Devil tree	*Alstonia venenata*	Apocynaceae	-	-	1	1	27th
71.	Sansami	Pattern wood	*Alstonia boonel*	Apocynaceae	-	-	1	1	27th
72.	Kawo	African mahogany	*Afzelia Africana*	Fabaceae	-	-	1	1	27th

Source: 2024 Survey

The respondents in the Study area focused on the location, their sex, marital status, age, occupation, experience, income per and their qualifications.

From Table 2, information on their sex revealed that 53 (84%) of the respondents were male while 10 (16%) were female. This implies that male is the dominant gender in the business and the result supported the findings of Ibrahim and Juma (2023). Information on their marital status reveals that 3 (5%) of the respondents were single, 57 (90%) of the respondents were married and 3 (5%) of the respondents were widow implying that majority of the herbalists are married.

The age dissemination of the respondents demonstrates that 9 (14%) are within the age of 20 - 30 years, 14 (22%) are in the range of 31 - 40 years, 18 (29%) are within the age range of 41 - 50 years, 14 (22%) are in the range of 51 - 60 years and 8 (3%) are above 60 years. However, none of the respondents have fallen in the range of less than 20 years. Based on the result of the questionnaire respondents within 41 - 50 years were dominants.

According to the data collected 32 or 24.62% were farmers, 30 or 23.07% were hunters, 27 or 20.77% were herdsmen, 22 or 16.92% were herbalists, 5 or 3.85% were civil servants, 9 or 6.92% were businessmen, 5 or 3.85% were other specified. However, none of the respondents was pastoralist. Based on the result shown 32 or 24.62% were farmers that dominated. In contrast, the lowest occupation was civil servants and other specified with 3.85% respectively.

In terms of Education, Table 2 shows that, 14 (22.22%) attended informal education, 11 (17.46%) with primary certificate, 19 (30.16) with BASIC/JSICE, 6 (9.52%) with SSCE/SSICE, 8(12.79%) with certificate/ND/NCE, 4 (6.35%) completed HND/Bachelor Degree and 1 (1.59%) MSc. Based on Table 1, respondents with BASIC/JISCE dominated and followed by informal education with 14 (22.22%). However, on the other hand 1 (1.5%) was the lowest. The information also revealed that 6 (9.5%) respondents have less than 5 years' experience, 4 (6.35%) have 11 -15 years' experience, 15 (23.81%) with 16 - 20 years' experience, 4 (6.35%) with 21 - 25 years' experience, 11 (17.46%) with 26 - 30 years' experience, 2 (3.17%) with 31 - 35 years' experience and 11 (17.46%) with more than 35 years' experience. This implies 15 (23.81%) Respondents have the highest working experience i.e. 16 - 20 years.

Based on the income per day of the respondents, table 1 shows that 2 (2.17%) respondents earned 100 - 200 per day, 1 (1.59%) earned 501 - 600, 5 (7.94%) earned 601 - 1000, 1001 - 2000 and 2001 - 3000 respectively. Also 39 (61.90%) of the respondents earned greater than 3000 per day. While none of the respondents earned 201 - 400 and 401 - 500 per day. The highest income per day dominated by 39 (61.99%) of respondents who earned more than 3000.

Table 2: Socio-economic Characteristics of Snakebite Envenomation Herbalists in North-eastern Nigeria

Parameters	Frequency	Percentage %
Sex		
Male	53	84.13
Female	10	15.87
Marital Status		
Single	03	4.76
Married	57	90.48
Divorced	-	-
Widowed	03	4.76
Age		
<20	-	-
20 – 30	09	14.29
31 – 40	14	22.22
41 – 50	18	28.57
51 – 60	14	22.22
>60	08	2.70
Occupation		
Farming	32	24.62
Hunting	30	23.07
Animal Rearing	27	20.77
Herbalist	22	16.92
Pastoralist	-	-
Civil servant	05	3.85
Business	09	6.92
Other specify	0.5	3.85
Experience		
<5	06	9.52
5 – 10	10	15.87
11 – 15	04	6.35
16 – 20	15	23.81
21 – 25	04	6.35
26 – 30	11	17.46
31 – 35	02	3.17
>35	11	17.46
Income per day		
100 – 200	02	2.17
201 – 400	-	-
401 – 500	-	-
501 – 600	01	1.59
601 – 1000	05	7.94
1001 – 2000	05	7.94
2001 – 3000	05	7.94
>3000	39	61.90
Educational Qualification		
Informal	14	22.22
Primary	11	17.46

Basic/JSICE	19	30.16.
SISCE/SSCE	06	09.52
Cert./ND/NCE	08	12.79
HND/Bachelor's Degree	04	6.35
Postgraduate	01	1.59

CONCLUSION

Snakebite envenomation treatment using medicinal plants is very critical development that has to be sustained and further develop in our society; with this survey reveling 72 plants in north-eastern zone of Nigeria, it is a great indication that there is available resource and with the range of age (20 to over 60 years) and experience of over 35years among the envenomation herbalists as well as majority having formal education, undoubtedly there is human resource for sustainably developing treatment of snakebites envenomation using medicinal plants.

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DIVERSITY AND COMPOSITION OF SOIL SEED BANKS IN SELECTED ROADSIDES IN PORT HARCOURT METROPOLIS, NIGERIA.

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ABSTRACT

Soil seed banks consist of viable seeds in the soil that have the ability of resorting adult plants. Its role is very vital in ecosystem. To species diversity in soil seed banks of four major roadsides (Aba Road, East/West Road, Ikwerre Road and NTA Road) in Obio/Akpor Local Government Area and a control (Ikwerrengwo) in Etche Local Government Area in Port Harcourt, Rivers State, Nigeria. Soil samples were obtained using systematic sampling technique at different soil depths (0-5cm, 5-10cm and 10-15cm) with the aid of a soil auger. Seedling emergence method was employed in analyzing the soil seed bank. Shannon-Weiner diversity index was used to determine the species diversity and evenness. A total number of twenty five species belonging to fourteen families were identified from the soil seed banks. Species such as *Oldenlandia* species, *Agerantum comyzoides*, *Pennisetum* species, *Elusine indica*, *Talinum triangulare* and *Mimosa* species were common at both the experimental and control sites. The soil seed banks studied revealed that the experimental and control sites were characterized by more grasses, more herbs and fewer trees and shrub. The number of species at the control site were more than the experimental sites. Thus, vehicular emission and man's disturbance of roadside soils has changed the diversity and composition of roadside soils.

Keywords: Soil Seed Bank, Metropolitan roads, Ruderals, Species Diversity, Species composition.

INTRODUCTION

Heavy metal pollution is one of the major environmental problems in today's world. It is of great interest to researchers because of its harmful effects to plants and invariably to animals and humans that consume them. Heavy metals can be defined as members of loosely defined subset of elements exhibiting metallic properties. They include some metalloids, transition metals, some actinides and lanthanides. They may include elements that are lighter than carbon and may exclude some heaviest metals. They occur naturally in our ecosystem with variations in their concentration.

The quest for urbanization and industrialization has led to a lot of anthropogenic activities which results to the increase in concentration of these metals to amounts that are harmful to both plants and animals. These activities include; municipal waste disposal, burning of fossil fuels, sewage sludge, waste-derived fuels, the use of fertilizers and pesticides in agriculture (Alloway, 1990; Raskin *et al.*, 1994; Shen *et al.*, 2002). High concentration of certain heavy metals such as Cd, Cr, Cu, Ni and Zn in soil disrupts the innate terrestrial and aquatic ecosystems (Gardea-Torresday *et al.*, 1996; Meagher, 2000). Elevated level of heavy metals in soil result in decrease in the growth rate of plants and it disturbs mainly the plants cellular redox environment which results to oxidative stress in the leaves and roots

of plants (Tamas *et al.,* 2008). Some of these heavy metals are very essential for plant growth at low concentration but at higher concentration may result in growth inhibition and metabolic disorders for some plant species (Fernandes and Henriques, 1991). Poisonous effects of heavy metals differ greatly among different plants (Leon *et al.,* 2002).

Seed bank plays vital roles in plant communities. Soil seed banks comprise of seeds that are viable in the soil that has the potential capabilities of replacing adult plants (Thompson and Grime, 1979; Baker, 1989). Most of the seeds in the seed bank come from nearby parent plants

while others are contributed by the communities of plants along some distance away from the parent plants (Solomon, 2011). Two main seed bank exist; transient types in which no seed remain viable for more than one year and persistent types in which seeds remain viable for more than one year (Thompson and Grime, 1979). Critical roles played by soil seed banks in the ecosystem include; differential species management, vegetation maintenance, ecosystem restoration, conservation of genetic variability and succession (Hills and Morris, 1992).

Roadside soils contain high concentration of heavy metals released from the wear and tear of automobile tyres, corrosion of car metal parts, oil leakage and burning of fuel (Dolan *et al.,* 2006). The toxicity of heavy metals in soil is a problem of increasing significance for ecological, nutritional and environmental reasons and these heavy metals are non degradable. Thus, the aim of this study is to evaluate the effects of vehicular emission on the soil seed bank of some major roadsides.

2.0 MATERIALS AND METHODS

Description of the Study Area.

This study was conducted along four busy roadside (East/West Road, Ikwerre Road, Aba Road and NTA Road) in parts of Obio/Akpor Local Government Area and the control in Ozuguru in Ikwerrengwo in Etche Local Government Area both in Rivers State Nigeria. The roads sampled are geographically located between latitude 4.891N to latitude 4.908N and longitude 6.902E to longitude 6.928E. The map of sampling area is presented in Figure 1. The study area experiences rainy and dry seasons. Rainy season starts from April and ends in October while dry season starts from November and ends in March

The climatic features of the study area include; high sunshine, high temperature, high relative humidity and high rainfall. The mean annual rainfall and temperature for 2015 were 134.5mm and 27.15^0C respectively (The Nigeria Meteorological Agency, 2016).

The nutrient content of the soil is usually low which is as a result of severe rainfall that leaches nutrients down the soil profile (Eludoyin *et al.,* 2011). Aba Road and East/West Road are among the major roads in Rivers State that links parts of Northern, Eastern and Western States with Rivers State, this results to a lot of traffic and exhaust fumes that emanate from both heavy duty and smaller vehicles are experienced along these roads. NTA Road and Ikwerre Road also experience heavy vehicular movement but of less traffic consequences when compared with the earlier two. Ozuguru in Ikwerrengwo (the control site) is a rural area and the residents there are mostly peasant farmers.

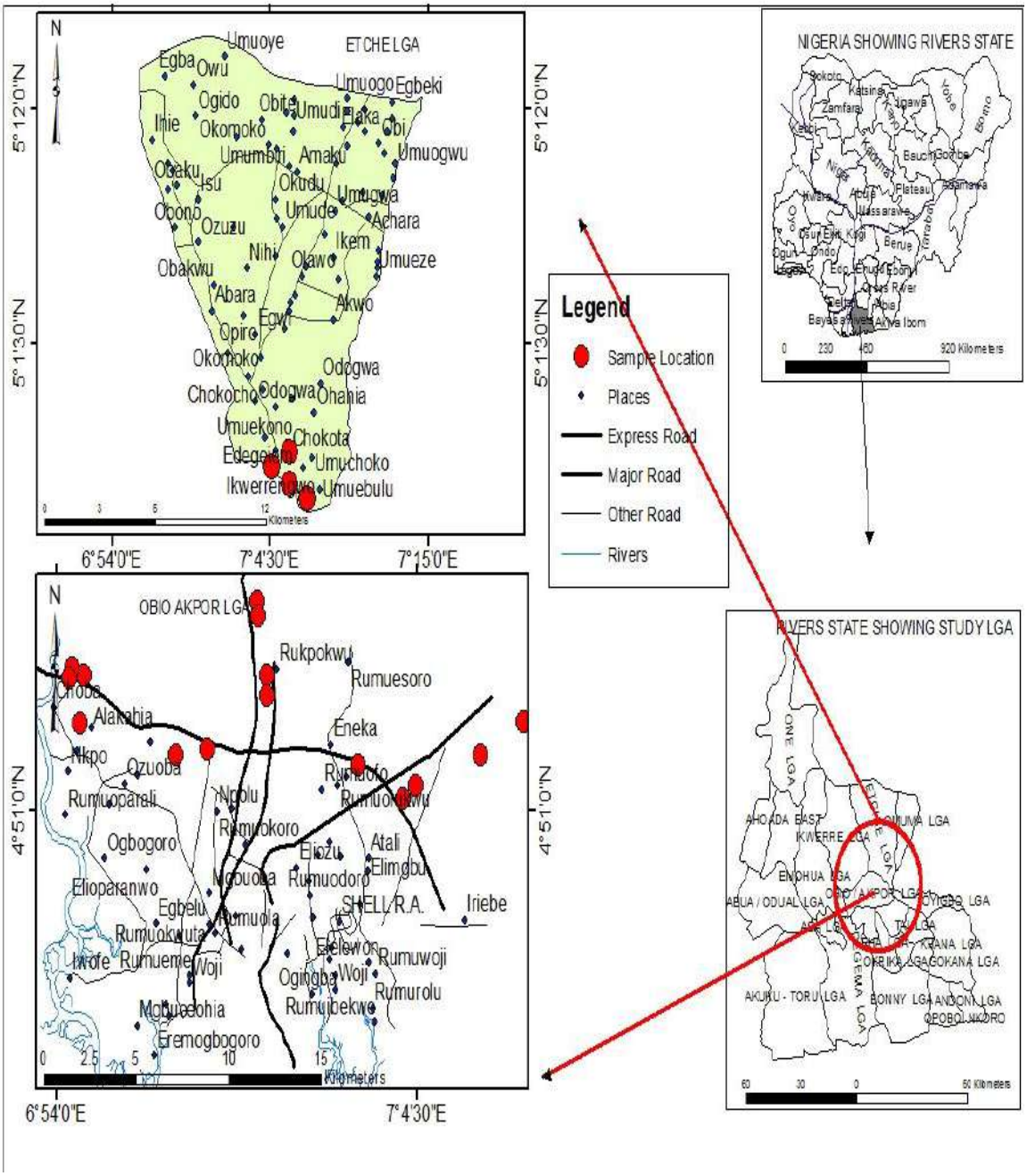

Figure 1: Map of sampling area showing the different sample collection at both the experimental and the control sites.

Sample Collection

Sampling and field data gathering were carried out during dry season in the months of February and March, 2019. The sample collection was done between the hours of 6.30a.m and 11a.m. Four sampling points were established along each of the experimental and control sites within a minimum distance of one kilometer each. At each sample point, three soil depths (0-5cm, 5-10cm and 10-15cm), they were collected with the aid of soil auger at a distance of one metre away from the edge of the road. The soils from each sample point were mixed thoroughly to form a composite sample and were transferred immediately into different sterile polyethene bags to prevent contamination from other sources, labeled with an indelible marker pen and were transferred quickly to the centre of Ecological Studies, University of Port Harcourt to determine the seed bank of the soil using seedling emergence method. A total of 60 soil samples were collected from both the experimental and the control sites.

The soils were sieved through a 2mm sieve to remove soil debris that were present in the soil, 100 grams from each sieved soil were put in a well labeled perforated bowl with a good diameter to give a thickness of 1 centimeter. The perforations at the bottom of the bowls were covered with Whatman filter paper No. 45 that prevented the soil from going out through the perforation. Each soil depth from each experimental site had three replicates making a total of one hundred and eighty bowls including the control group. The soils in the perforated bowls were watered daily, exposed to sunlight during the day and were covered with a transparent board whenever it wants to rain to prevent loss of weed seeds that might occur due to rain splash. The soil were observed daily, two days after initial watering of the soil, seedlings started emerging. The seedlings were identified and counted weekly by a plant taxonomist after which they were carefully uprooted with the aid of a spatula and were discarded while the experimental and control soils were watered daily. At the end of every two weeks intervals, after the seedling identifications and uprooting of the germinated seedlings, the soil in each bowl were turned and homogenized while the old Whatmann filter paper were removed and replaced with new ones with the same soil back to the same bowl. This was done for six weeks (compressed seed bank) before discarding the soil.

RESULTS

The results of the number of plant family, species, diversity and evenness at the experimental and control site is presented in Table 1. A total of 25 species belonging to 14 families were identified at the above ground vegetation. These include 17 annuals and 8 perennials. The result showed the different types of plant species, their families, the number of individual species, species diversity and evenness.

The total number of species found at Aba Road soil were 17 species, East/West Road had 19 species, Ikwerre Road had 15 species, NTA Road had 18 species and the control site had 22 species. This indicates that the control site had the highest species diversity. The diversity at the control and experimental sites were in this order; control site> Ikwerre Road > Aba Road > NTA Road > East/West Road. The dominant species at Aba Road were *Oldenlandia species* and *Pennisetum species* and the sparsely present species were *Solenostemon monotachy* and *Aspilia africana.* In East/West Road, the dominant species were *Oldenlandia species, Agerantum comyzoides* and *Pennisetum species* while sparsely present species were *Alterandhera species, Cynodon dactylon* and *Echinochloa species.* The dominant species at

Ikwerre Road were *Agerantum comyzoides, Oldenlandia species* and *Eleusine indica* while sparsely present species were *Paspalum species, Alterandhera species* and broad leaves. At NTA Road, the most dominant species were *Oldenlandia species, Ageranthum comyzoides* and *Cynidin dactylon* while sparsely present species were *Panicum maximum, Solenostemon monotachy* and *Echinochloa species.* At the control site, the most dominant species were *Agerantum comyzoides, Alterandhera species* and *Digitaria species* while sparsely present species were *Carex appressa, Boerhavia species,* and *Dactyloctinum aegyptium.*Ikwerre road had the highest evenness while East/West road had the least.

From the Table, it was observed that species such as *Oldenlandia species, Agerantum comyzoides, Pennisetum species, Elusine indica, Talinum triangulare* and *Mimosa species* were common at both the experimental and control sites. The soil seed bank studied revealed that the experimental and control sites were characterized by more grasses, more herbs and fewer trees and shrub.

Table 1: Seedling Emergence from the Soil Seed Bank of Roadsides in Port Harcourt Metropolis, Nigeria

S/N	Plant Species	Family	Plant Form	Aba Road	East/West Road	Ikwerre Road	NTA Road	Control Site
1	*Oldenlandia species*	Rubiaceae	Herb	142	82	16	70	14
2	*Agerantum comyzoides*	Asteraceae	Herb	49	79	22	21	34
3	*Carex appressa*	Cyperaceae	Grasses	0	5	0	6	1
4	*Paspalum species*	Poaceae	Grasses	22	20	1	9	0
5	*Eleusine indica*	Poaceae	Grasses	18	8	12	5	4
6	*Talinum triangulare*	Portulacaceae	Herb	12	5	5	4	2
7	*Mimosa species*	Fabaceae	Tree	22	19	7	5	6
8	*Phyllanthus species*	Phyllanthaceae	Tree	11	12	8	14	0
9	*Acalypha species*	Euphorbiaceae	Shrub	0	2	2	4	2
10	*Alterandhera species*	Amaranthaceae	Grasses	0	1	1	9	20
11	*Cynodon dactylon*	Poaceae	Grasses	31	1	2	16	8
12	*Digitaria species*	Poaceae	Grasses	0	6	0	0	17
13	*Aspilia Africana*	Asteraceae	Herb	3	0	3	4	10
14	*Lindernia species*	Linderniaceae	Grasses	41	0	0	3	16
15	*Axonopus compresus*	Poaceae	Grasses	11	8	2	0	9
16	*Pennisetum species*	Poaceae	Grasses	92	62	8	13	16
17	*Boerhavia species*	Nyctagineaceae	Herb	0	6	0	0	1
18	*Amaranthus species*	Amaranthaceae	Herb	8	3	2	0	3
19	*Echinochloa species*	Poaceae	Grasses	0	1	0	1	2
20	*Schwenckia americana*	Solanaceae	Grasses	0	0	0	0	2
21	*Portulaca species*	Portulacaceae	Herb	4	0	0	2	0
22	*Solenostemon monotachy*	Lamiaceae	Tree	2	0	0	1	3
23	*Panicum maximum*	Poaceae	Grasses	10	2	2	1	3
24	*Broad leaves*	Plantaginaceae	Herbs	16	11	1	2	7
25	*Dactyloctinum aegyptium*	Poaceae	Grasses	0	0	0	0	1

No. of species	**17**	**19**	**15**	**18**	**22**
No. of individuals	**494**	**333**	**246**	**190**	**181**
Species Diversity	**2.287**	**2.008**	**2.362**	**2.096**	**2.637**
Species Evenness	**0.13**	**0.11**	**0.16**	**0.12**	**0.12**

DISCUSSION

The contaminations of soil by heavy metals result in different adverse effects on the growth of plants. These include poor physical structure, reduction in micro nutrients, alkalinity, concentration of toxic metals etc (Bradshaw and Chadwick, 1982). Result obtained from the soil seed bank studied revealed different plant communities at both the experimental and control sites. From the result, it was observed that the soil from the control site had more grasses from different families than the experimental sites. The reduction in the number of grasses at the experimental sites could be attributed to different contaminants that emanate from different diffuse and point sources that settle on the soil thereby suffocating plants and soil microbes since soil are major terrestrial sink for pollution. This is in line with Giller *et al.* (1998) who reported that metal contamination result in poor plant yield and quality and changes the activities and composition of soil microbes. Yao *et al.* (2003) showed the adverse effect of heavy metals on soil microbial community. Also, Kandeler *et al.* (1996) reported reduction in the diversity of functional microbial communities due to heavy metals. From the result, it was also observed that the number of trees identified from the soil seed bank studied were more from the control site than the experimental sites. This concurs with the findings made by Yao *et al.* (2003) that heavy metals cause great reduction in species diversity of soil microbial communities. It was observed that *Schwenckia americana* was only identified in the soil from the control site. This agrees with Shu *et al.* (2002) who reported that heavy metals might cause serious phytotoxic effects and could act as a propelling force in the change of tolerant population. Also, the control site had the highest diversity index calculated. Yao *et al.* (2006) also observed reduction in population diversity of microbial communities in a Cu polluted red soil. Also, Kandeler *et al.* (1996) reported reduction in the diversity of functional microbial communities due to heavy metals.

From the result, it was observed that there was reduction in species diversity at the experimental sites than the control site which could be due to the increase in heavy metal pollution at the experimental sites.

CONCLUSION

The soil seed bank studied showed that the seed bank were of persistent type. Studies on soil seed bank help in the identification of qualitative and quantitative determination of viable seeds that were buried beneath the soil. As a major component in vegetative dynamics, it plays vital roles in ecosystem restoration, succession, vegetative maintenance and conservation of genetic variability and the management of differential species. It also brings to the knowledge of researchers the types of seeds that are present in a particular soil.

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EDITED ABSTRACTS

ECOABR001

Implementation of Ecosystem-Based Management in the South-South Region of Nigeria: A Coastal Resources and Environment Conservation Approach

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ABSTRACT

The coastal environment within South-South Nigeria (SSN) has suffered significant degradation resulting from the direct and indirect impacts of anthropogenic activities. These include mining, emission of industrial waste, smelting of As-ore, combustion of fossil fuels, notably coal, and disposal of some As-based insecticides, herbicides, and fertilizers into the waterbodies. Recently, the conservation of these coastal environments and resources has gained more attention, especially in the face of climate change. Although, various approaches have been established and enforced yet no significant impact. Hence the need for a more efficient and effective approach gave rise to the adoption of ecosystem-based management (EBM) which has aided the effective management of the freshwater resources and environments. This is an approach that acknowledges the complete range of interconnections within an ecological system, involving people, rather than focusing only on particular concerns, species, or ecological services. The implementation of EBM has been a challenge due to the diversity of the coastal environment, however, it has been effectively used in the management and conservation of freshwater bodies. This review therefore looks at the possibility of implementing EBM in the conservation of the coastal environment and its resources. Consequently, a holistic implementation of EBM is however discouraged suggesting an implementation in phases taking into account the unique nature and components of the SSN coastal environment. In addition, the necessary indicators such as organism present, species abundance, thresholds involved, range of threats and disturbances, data evaluation and usage, and monitoring strategies need to be considered.

Keywords: Coastal environment, Ecosystem degradation, Resource exploitation, Ecosystem-based management, Industrial pollution

ECOABR002

EVALUATING SOIL SEED BANK IN *Musa parasidiaca* and *Elaeis guineensis* FARMS IN SOUTHERN NIGERIA

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ABSTRACT

Importance of soil seed bank of *Musa parasidiaca* farm (plantain) and *Elaeis guineensis* (oil palm) at IITA high rainforest station Onne and University of Port Harcourt respectively were evaluated. Soil samples were obtained from the two locations at 0-5 cm, 5-10 cm, 10-15 cm depths respectively. The soils were assessed at Centre of Ecological Studies, University of Port Harcourt, Rivers State, Nigeria. Seedling emergence plant identification and enumeration were recorded for of eight weeks and statistically analyzed. The plantain farm had 30% of total number of emerged seedlings, while it was 70% for oil palm farm. Sixteen families including Poaceae (six species), Asteraceae family (four species); and families Rubiaceae, Lamiaceae and Solanaceae with two species each were identified. Highest total number of seedlings was encountered at 5 cm depth followed by 10 cm and 15 cm. The study confirmed that depths have significant effect on the total number of seedlings in the soil. Plant species most commonly observed across all depths in the two locations were *Oldenlandia corymbosa, sedges* and *Lindernia* sp. Sixteen plant species emerged from soil of plantain farm, containing ten annual broad leaves, three annual perennial broad leaves, one annual grass and two perennial grasses. The soil samples from oil palm contained a total of twenty-three plant species including thirteen annual broad leaves, three annual perennial broad leaves, two annual grasses, three perennial grasses, one fern and one perennial broad leaf. Future regeneration of plant species and maintenance of good diversity are possible within the study area.

Keywords: Plantain, oil palm fields, species composition, soil seed bank, species diversity, species richness

ECOABR004

Impacts of *Bauhinia monandra, Delonix regia* and *Tetrapleura tetraptera* on the physicochemical quality of crude oil-contaminated soil at 16 weeks after planting in Nigeria

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ABSTRACT

This study investigated the impacts of *Bauhinia monandra*, *Delonix regia* and *Tetrapleura tetraptera* on the physicochemical quality of crude oil-contaminated soil at 16 weeks after planting. The experimental setup was carried out in a greenhouse. Varying level of crude oil was made to spillage concentration of 0.0, 0.63, 1.25, 1.88 and 2.5 %v/w. Then after *Bauhinia monandra*, *Delonix regia* and *Tetrapleura tetraptera* planted in different experimental plots. At 4, 8, 12 weeks after planting, the soil samples from each of the pots were anlyzed for physiochemical chracteristics following stanadard procedure. The result revealed a decline in all the parameters viz: total nitrogen, phosphorous, pH, electrical conductivity, soil organic carbon and matter, calcium, sodium, magnesium and potassium as the concentration of the crude oil increased. *Delonix regia* and *Bauhinia monandra* decreased in soil acidity and soil planted with *Delonix regia* increased in N and other soil macronutrients. There was increase in the nutritional status, and may be due to increased N-fixation in the root nodules of the leguminous trees. In addition, available soil P also increased in the leguminous trees planted soil at the end of the 16-week period. The tendency of these leguminous trees to survive in the contaminated soil suggests their potentials for phytoremediation of crude oil from the soil.

Keywords: Crude oil, Environmental Contamination, Leguminous Trees, Phytoremediation.

ECOABR005

DETERMINATION OF METAL CONTENT IN A SEGMENT OF NEW CALABAR RIVER, NIGERIA USING TWO PLANT SPECIES AS BIOINDICATORS

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ABSTRACT

The extent of contamination of sediment, water and some selected plant species (bio-indicators) of the New Calabar river by heavy metals were examined. Three sample locations along the River, namely; Aluu , Choba and Rumuokparali were selected for the study. Water, sediment and two plants [*Cyrtosperma senegalense* (Scholt) Engl.) and *Pandamus candelabrum* (P. beauv)] were sampled and analysed for heavy metals [Lead (Pb), Copper (Cu), Iron (Fe), Cadmium (Cd), Zinc (Zn) and Chromuim (Cr)] contents using Atomic Absorption Spectrophotometer (AAS) in addition to the Conductivity and pH of the water and sediment samples. Results indicated high concentrations of heavy metals in the sediments, plants and water samples of Aluu and Choba while low concentrations were detected in Rumuokparali. It was also observed that the pH of sediment and water were acidic and the conductivity were high. The sediment accumulated more heavy metals than the water. *Cyrtosperma senegalense* accumulated higher concentration of Zn and Fe at Aluu and Choba respectively. *Pandamus candelabrum* also accumulated higher concentration of Zn and Pb at Aluu. The level of accumulation of the metals in the plants compared to the surrounding medium shows that *Cyrtosperma senegalense* and *Pandamus candelabrum* can be used for biomonitoring of metal contamination in the aquatic system.

Keywords: Heavy metals, Contamination, Sediment, Water, New Calabar river, *Cyrtosperma senegalens, Pandanus candelabrum.*

ECOABR006

Assessing Stand Volume Models and Form Factors of Tree Species in Omo Biosphere Reserve, Ogun State, Nigeria

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ABSTRACT

Form factors and stand volume models were estimated for volume of trees at Omo Biosphere Reserve Ogun state, Nigeria. Systematic sampling technique was adopted to lay three line transects at 100 m intervals. Four temporary plots of 50 m x 50 m were laid in alternate position at 100 m interval along each transect. All woody plants ≥ 10 cm were enumerated for diameter at breast height (dbh), diameter over bark at the base, middle and top (db, dm, dt), and total height. Volume of each tree was also generated using the modified Newton's formula. Data collected were subjected to correlation analyses and models were developed using R statistics package, and were evaluated by confirming the goodness of fit of the models, Akaike Information Criteria (AIC) and RMSE were used to select the best model. A total of 429 trees from 60 species and 30 families were recorded. *Diospyros dendo* was the dominant species with 79 stems/ha. Ebanaceae and cannabaceae family had the highest number of species**.** Mean dbh and mean height ranged from 12.2 – 135 m and 3.2 -34 m respectively, Total BA and Average volume per hectare were 39.169 m^2 and 0.938 m^3 respectively, form factors varied from 0.26 to 38.56 with the highest value recorded for *Diospyros dendo* (38.56) and the lowest value recorded for *Irvingia wombolu* (0.26). Highest correlation coefficients were obtained between diameter at breast height (dbh) and diameter over the bark (db) which is 0.97. The combined variable model 3 using D^2H ($V = 0.25 + 0.14\ D^2\ H$) as the predictor gives the best output and was ranked the best model with the highest R and R^2 (0.962 and 0.961), lowest AIC and BIC (646.486 and 665.359) respectively. In conclusion this study demonstrated that the generated models are desirable for tree volume estimation in the study area and at similar ecosystems and can be helpful in matters concerning forest inventorying and management.

keywords: Natural forest, Stand volume models, Form factors, Tree volume estimation, Sustainable management, Forest mensuration

ECOABR008

EFFECTS OF SEDIMENT COMPOSITION ON AQUATIC ECOSYSTEMS

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ABSTRACT

Sediment composition plays a crucial role in shaping the structure and function of aquatic ecosystems. Sediment, as a complex matrix of mineral particles, organic matter, and microbial communities, interacts with water and organisms to influence habitat quality, nutrient cycling, contaminant transport, and biodiversity. Sediment texture, characterized by particle size distribution, determines habitat suitability for benthic organisms and influences sediment stability and erosion rates. Fine sediments tend to accumulate contaminants and organic matter, impacting water quality and oxygen availability through processes such as hypoxia and eutrophication. Conversely, coarse sediments provide refuge and spawning grounds for certain species of organisms, while promoting nutrient exchange and bioturbation. Sediment composition significantly influences chemical processes such as nutrient retention and release. Organic carbon content regulates sediment oxygen demand and nutrient availability, influencing primary productivity and species composition. Microbial activity is highly sensitive to sediment composition, with implications for ecosystem functioning and the fate of pollutants. Interactions between sediment microbes and benthic fauna can shape community dynamics and trophic interactions within aquatic ecosystems. Understanding the effects of sediment composition on aquatic ecosystems is essential for effective management and conservation strategies. Integrated approaches that consider sediment dynamics alongside water quality and habitat restoration efforts are crucial for maintaining ecosystem resilience and supporting biodiversity in the face of anthropogenic pressures and environmental change. This paper underscores the need for interdisciplinary research and management approaches to address the complex interactions between sediment composition and aquatic ecosystem dynamics.

Keywords: **S**ediment composition, aquatic systems, biodiversity.

ECOABR009

SPHAGNUM MOSSES (BOG/QUACK MOSSES) FOR BIOREMEDIATION: A REVIEW OF ENVIRONMENTAL POLLUTION CLEANUP STRATEGIES

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ABSTRACT

Sphagnum mosses, also known as bog/quack mosses are known for their unique traits and ecological relevance in peatlands, have emerged as viable alternatives for bioremediation of environmental contamination. This review investigated the use of sphagnum mosses in pollution clean-up efforts, with a focus on their usefulness in mitigating various forms of contamination. The review considered underlying mechanisms that allow sphagnum mosses to absorb and detoxify contaminants such as heavy metals, organic pollutants, and surplus nutrients in a variety of ecosystems, including wetlands, urban areas, and agricultural lands. Furthermore, practical applications of *Sphagnum* mosses in real-world bioremediation efforts been assessed, giving insight on their benefits, potential and limitations. By synthesizing available studies, the review aimed to provide useful insights into the varied role of sphagnum mosses in pollution reduction. It aimed to advance scientific understanding of *Sphagnum* mosses bioremediation capabilities and their incorporation into sustainable environmental management techniques. It further exposed researchers, policymakers, and environmental practitioners to the importance of sphagnum mosses as eco-friendly solutions to addressing environmental pollution, encouraging a more resilient and sustainable future.

Keywords: Bioremediation, Environmental contamination, *Sphagnum* mosses, Sustainable management.

ECOABR010

Restoration of Crude Oil Contaminated Wetland by the Muit-Talented *Trichoderma* Species

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ABSTRACT

The contamination of soil with crude oil poses a great threat to the environment, affecting its fertility and overall ecosystem health. This study investigated the potential of *Trichoderma* species as an amendment to stimulate the remediation of crude oil polluted soil. The effectiveness of *Trichoderma* species in enhancing the degradation of crude oil was evaluated by measuring key parameters, such as total petroleum hydrocarbon (TPH) content, microbial activity. Preliminary results indicated that the addition of *Trichoderma* species significantly enhanced the degradation of crude oil in the polluted soil. The TPH content decreased in the treatment groups compared to the control group, from 2078 ppm to 312 ppm for T2 % and 3885 ppm to 1247 ppm for T10 %. PAHs have a reduction of 11.63 ppm to 0.11 ppm for T2 % while T10 % recorded 30.27 ppm to 2.83 %. Microbial activity, as indicated by the increased population of hydrocarbon-degrading bacteria, unamended set-up recorded 1.15×10^4 cfu/g – 4.8×10^5 while the amended recorded 2.3×10^5 cfu/g – 6.6×10^7 cfu/g. This indicated a significant improvement in the *Trichoderma*-amended soil samples. These findings suggest that *Trichoderma* species have the potential to stimulate the bioremediation of crude oil-contaminated soil. The metabolic capabilities of *Trichoderma*, such as hydrocarbon degradation and plant growth promotion, contributed to the overall improvement of soil health and restoration of ecosystem functionality. Further investigations are needed to optimize the application of *Trichoderma* species in large-scale bioremediation projects.

Keywords: *Trichoderma* spp. Stimulation, Crude Oil, Bioremediation, Nitrate.

ECOABR0011

WETLAND VALUATION AND MANAGEMENT IN NIGERIA

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ABSTRACT

Wetlands are unique, productive and most diverse ecosystems that provide numerous ecological, social and economic benefits to humans and the environment. Wetlands in Nigeria cover about 10% of the land area and provide integral ecological services including water storage and flood control, timber and non-timber products, water filtration, carbon storage, fisheries, shore stabilisation, storm protection, habitat diversification and conservation.. Human activities stemming from urbanization, agriculture, oil and gas exploration and exploitation activities, inadequacy of legal regulations are serious threats to wetlands in Nigeria.. This paper established that there is utmost need for wetland valuation and management to save them from the avalanches of over exploitation and degradation using different strategies, including adequate funding, conservation programmes, community-based wetland management, aggressive environmental education, institutional capacity building, watershed stewardship and aquatic aquifers with a view to reducing the current heightened wetland collapse and degradation. Wetland valuation aims at the mortage, insurance, sales/purchases, compensation and public goods as well as for informed balanced decision-making regarding their protection besides building local and political support for sustainable use.

Keywords: Environmental degradation, Wetland valuation, management, sustainable development, watershed stewardship.

ECOABR012

Planting Density Effect on Growth, Dry Matter Accumulation and Weed Control Efficiency of *Indigofera hirsuta* Linn. in Ibadan, Nigeria

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ABSTRACT

A field experiment was conducted at the Crop Garden, Department of Crop Protection and Environmental Biology, University of Ibadan, Nigeria to investigate the effect of planting density on the performance of *Indigofera hirsuta* and its ability to suppress weeds. Seeds sown at 1 cm soil depth were spaced at 20 cm inter-row and varying intra-row spacings, 10, 20, 40, 80 and 160 cm to have densities 50, 25, 12.5, 6.25 and 3.13 plants/m^2 which are equivalent to 500,000, 250,000, 125,000, 62,500 and 31,250 plants/ha, respectively. Plots where *I. hirsuta* were not planted served as the control. The experiment was conducted in two trials in a randomised complete block design replicated three times with the five densities and control randomly allocated to plots in each block. The plant height (PH, cm), stem diameter (SD, cm), shoot dry weight (SDW, kg) and weed dry weight (kg) were measured at 14 weeks after planting and the treatments compared using ANOVA. The PH of *I. hirsuta* at density 3.13 plants/m^2 (105.0 – first trial and 107.0 – second trial) were significantly higher than the heights recorded in other test densities. The SD and SDW at density 3.13 plants/m^2 (0.97 cm and 0.38 kg – first trial; 0.93 cm and 0.38 kg – second trial) were significantly higher than the SD and SDW recorded in other test densities. The weed dry weight on 50 plants/m^2 plot (0.55 kg and 0.59 kg in the first and second trial, respectively) was significantly lower than those on the other plots. *Indigofera hirsuta* proved effective in suppressing other weeds, which increased with increasing density. The weed suppressive ability of *Indigofera hirsuta* is attributed to competition for light due to its rapid growth and spreading habit.

Keywords: Live mulch, cover crop, sown fallow, spacing, weed control, *Indigofera hirsuta*.

ECOABR013

PHYTOPLANKTON CULTIVATION USING LEAVES EXTRACT CULTURE

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ABSTRACT

This project explores an innovative approach to enhancing phytoplankton cultivation by introducing leaf extract into algal growth medium as a growth-promoting agent. Phytoplankton plays a vital role in aquatic ecosystems by serving as a primary food source for various aquatic organisms and contributing to carbon dioxide sequestration. However, their growth is often limited by nutrient availability. In this study, we investigated the potential of leaf extract as a nutrient-rich supplement to improve phytoplankton biomass. The research involves collecting leaves from various plant species and processing them into their various extracts. The leaves extracts were then added to algal growth medium in a controlled environment to assess their impact on phytoplankton growth. The objectives of project were to monitor changes in phytoplankton biomass, and evaluating alterations in species composition and biodiversity. Preliminary findings indicated that the introduction of leaf extract positively influenced phytoplankton growth. The project outcome has significant implications for ecological restoration, aquaculture and sustainable environmental management practices by harnessing the natural nutrient content of leaves. This approach offers a promising avenue for enhancing phytoplankton cultivation and consequently the health of aquatic ecosystems.

keywords: Phytoplankton, Leaf extract, Algal growth, Carbon sequestration, Ecosystem restoration.

ECOABR014

Impact Evaluation of Sewage Discharge on Water Physico-chemical Properties of the New Calabar River at Rumuolumeni, Port Harcourt, Nigeria

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ABSTRACT

Impact evaluation of sewage discharge on water physical and chemical properties of the New Calabar River at Rumuolumeni, Port Harcourt using FEPA (2003) and WHO (2011) as regulatory standards was carried out to assess selected physico-chemical properties water and determine the health status of the ecosystem. The littoral zone of a sewage discharge site at Minikpiti, Rumuolumeni was divided into three zones of 10 m intervals from the low tide mark into the river channel. Water samples were collected from each of the zones following standard procedures, labeled and analyzed. Results obtained showed that temperature fluctuated between 28 and 35 ºC and was below the standards. pH decreased from 5.2 to 4.2 down the zones and was below the standards. Total dissolved solids decreased into water channel from 522 to 374 mg/l and was below FEPA (2003), while dissolved oxygen increased from 1.5 – 3.1 mg/L into water channel and was below WHO (2011) standard. Biological oxygen demand decreased from 403.2 - 309.4 mg/l into water channel and was higher than WHO (2011) standard, phosphate content increased from 0.96 mg/l – 2.12 mg/L into water channel and higher than WHO (2011) standard, nitrate content (0.68 – 0.41 mg/L) decreased into water channel and below the standards. Based on FEPA (2003) standard, the New Calabar River at Rumuolumeni is impacted and polluted by sewage discharge into it. Thus, the status of river poses risk to the sustenance of its ecosystem and services and therefore requires the implementation of pollution control measures.

Keywords: New Calabar River, Sewage Discharge, Biological Oxygen Demand, Physico-chemical Properties, Impact Evaluation.

ECOABR014

Wetland Degradation and Loss Resulting from Poor Waste Management Practices in Yenagoa and Environs, Bayelsa State, Nigeria

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ABSTRACT:

Globally, the size of wetlands has been on the decline due to the fragile nature of these ecosystems and unplanned land consumption practices. Before the creation of Bayelsa State and Yenagoa made the state capital, wetlands and agricultural land-uses dominated the landscape of the area. However, the Yenagoa urban have undergone tremendous transformation in land- use/landcover and impacted its surrounding environment, due to rapid urbanization, increasing population growth and urban development since 1996. One impactful area of Yenagoa's development is the poor management of its municipal waste. Wastes generated and collected from the urban area are disposed of into the surrounding wetland areas, with the sole aim of reclaiming more land for use. Typical examples are the waste dump sites opposite the Gbarain Location and the other on the Location Road to Obunagha. Wetlands are complex ecosystems that provide many ecological, biological, and hydrologic functions that are of great value to society. Consequently, wetlands are increasingly valued for conservation over converting them for non-environment-friendly and economic uses. The poor reflection in conservation and development planning of the greater Yenagoa Capital by the authorities is of great concern. Wetlands destruction through waste dumping affects negatively the ecosystem functions and resource management. This paper examines the poor municipal waste management efforts of Yenagoa and effects on wetlands and recommends that efforts to achieve sustainable, effective, and equitable wetlands conservation and management be put in place. The development of deliberate restoration programmes and policies aimed at sustaining the degraded wetlands in Bayelsa is recommended.

Keywords: Wetland degradation, Municipal waste management, Ecosystem services, Wetland conservation, Ecosystem restoration.

ECOABR016

TODAY'S MERE SYMBOLISM, ISN'T IT? : IMPLICATIONS OF PROMINENTLY MENTIONED TREE BACKGROUNDS IN SOUTH WESTERN NIGERIA: AN AGENDA FOR RE-STORATION AND INVENTORY.

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ABSTRACT

Conservation biology centers on perpetual nurturing and preservation of biodiversity/organisms as renewable resources. In South western Nigeria, the catchment area comprising Ekiti, Lagos, Ogun, Ondo, Osun and Oyo States, there are symbolic tree backgrounds that may still practically exist or in some instances may have become locally extinct. A review of scientific literature was carried out on the subject matter January, 2024 till date. Eight prominent trees in seven angiospermic plant families were documented. *Adansonia digitata* (Bombacaceae), *Albizia* spp. (Mimosoideae - Fabaceae), *Bligha sapinda* (Sapindaceae), *Ceiba pentandra* (Bombacaceae), *Irvingia gabonensis* (Irvingiaceae), *Mangifera indica*(Anacardiaceae),*Milicia excels* (Meliaceae) and *Triplochiton scleroxylon* (Sterculiaceae) tops the list of neigbourhood streets and living quarters. Rigorous re storation efforts should be practicalised to stem this problematic situation of mere symbolism by growing and nurturing back these afore mentioned trees and other tree plants.

Keywords: Conservation biology, Tree backgrounds, Species Inventory, Renewable resources.

ECOABR017

TEMPORARY AND SPATIAL VARIABILITY IN MICROALGAE COMMUNITY STRUCTURE IN RELATION TO ENVIRONMENTAL VARIABLES IN NSIT UBIUM RIVER, AKWA IBOM STATE, NIGERIA

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ABSTRACT

This study investigated the temporal and spatial variability in microalgae community structure of Nsit Ubium River, with a view to determine how its ecological dynamics are influenced by environmental variables. Two key stations: Inyang Udo Nsinia Stream (Station 1) and Ikot Okobo Stream (Station 2) were studied over six months in wet and dry seasons. Spatial grid sampling, species identification and physicochemical variables collected and analysed using standard procedures. A total of 56 algal species from six orders were identified, with Bacillariophyta dominating both stations. Distinctive spatial patterns in algal occurrences, with variations in Bacillariophyta, Dinoflagellates, Chlorophyta, Euglenophyta, Cyanophyta, and Glaucophyta were observed across the two stations. The study also presents percentage occurrences of identified algal orders and physicochemical parameters of the river. The rich biodiversity of Nsit Ubium River calls for extended sampling durations and dissolved oxygen measurements in future research. Long-term monitoring programs and collaboration among relevant stakeholders are needed to effectively integrate conservation initiatives into environmental management plans for the preservation of Nsit Ubium River's unique ecosystem health.

Keywords: Nsit Ubium River, Microalgal communities, Temporal and spatial variability, Ecological dynamics, Environmental variables.

ECOABR018

TOLERANCE OF STRANDLINE PLANTS, *Diodia maritima* Thonn (BOTTONWEED) AND *Kyllinga peruviana* Lam (Peruvian Spikesedge) TO WATERLOGGING: SUITABILITY FOR COASTAL SHORE LANDSCAPING

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ABSTRACT

Strandlines are areas created along the high water mark which occur on a range of habitats including coastal vegetated shingle, coastal sand dunes and coastal salt marshes. Waterlogging is one of the ecological factors affecting strandline plants, as flood from sea may be caused by heavy storm, high tides and wave action. Flood-tolerant plants are important to landscapers in such a wetland ecosystem due to high mortality of conventional ornamental plants in coastal communities. *Diodia maritima (*bottonweed*)* and *Kyllinga peruviana* (Peruvian spikesedge) are among the few plant species occurring naturally, highly restricted and widely distributed strandline plants in West Africa, particularly Nigeria. Bottonweed and Peruvian spikesedge were subjected to induced drought and waterlogging to investigate their responses and suitability for landscaping in coastal shore ecosystems. The plants were exposed to water regime consisting of watering daily (WD), every 3 days (WT), every 7 days (WS), every 14 days (WF) and permanent waterlogging (WL). Changes in morphology, survival, growth, biomass allocation, ion accumulation and water status of the plants were studied in response to waterlogging and drought. Drought caused leaf chlorosis, early leaf senescence, reduced leaf size and leaf folding in the plant species. Growth of the plants was significantly reduced by water stress, with more tolerance to waterlogging than drought. The plants are tolerant to flooding with adaptations for survival in the strandline. They are, therefore, suitable for coastal shore landscaping.

Keywords: Growth; Ecophysiology; Adaptation; Flooding; Landscaping: Coastal Ecosystem, Strandline Plants

ECOABR020

Phytoremediation potential of plants growing on a waste dump site in the vicinity of an Oil and Gas Company in Kwale, Delta State, Nigeria

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ABSTRACT

The study explored the phytoremediation potential of some plant species collected from a waste dump site. Soil and plant samples from the dump site and a control site were analysed for selected heavy metals (Fe, Pb, Zn, Cu , Cr, Cd and Ni). The phytoremediation potential of plants was assessed using the bioaccumulation factor (BAF) and translocation factor (TF) while soil pollution levels were evaluated using the contamination factor (CF), geoaccumulation index (I_{geo}) and enrichment factor. The result revealed that the order of mean concentrations of the heavy metals in the soil samples was in descending orders Fe> Zn > Pb > Cu > Cr > Ni. The result also indicated that contamination factor values for Fe, Pb, Zn , Cu and Cd were > 4 indicating high contamination which could be traceable to petroleum, commercial and domestic activities in the vicinity Enrichment factor values for Fe, Pb, Cr were 2 < EF < 5 indicating moderate enrichment. The trend of Fe > Cu > Zn > Pb >Co >Cr> Ni was observed in plant samples. Transfer factor revealed that plants growing in dump site accumulated higher metal concentration than same plant in the control site indicating that dump sites contained high concentration of heavy metals which are absorbed and subsequently accumulated by the plants growing in the dump site. The translocation ratio of metals suggests that absorption is in the order root > stem > leaves. All the studied plants revealed good phytoremediation potential, with translocation factor values between 1.62 to 2.03 classifying *Jatropha curcas* and *Ricinus communis* as high phytoextractor plants. This study has created the awareness of soil pollution and opportunities for sustainable and eco-friendly remedial measures like phytoremediation especially in oil exploration environments.

Keywords: Bioaccumulation of metals, dump site, phytoremediation, *Jatropha curcas, Ricinus communis*.

ECOABR021

PRINCIPAL COMPONENT ANALYSIS OF SOIL PHYSICOCHEMICAL PROPERTIES INFLUENCING TREE SPECIES GROWTH IN CROSS RIVER NATIONAL PARK, OBAN DIVISION

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ABSTRACT

Basic ecological data is mandatory if a forest and tree species found therein is to be effectively regulated, managed, conserved or restored in a sustainable way. This study used the systematic sampling method and quadrats to assess the composition and diameter at breast height (dbh)/height of forest tree species at the Cross River National Park (CRNP), Oban Division, and to analyse soil physico-chemical properties and soil properties that influenced the growth of tree species in the CRNP, Oban. Only tree species with dbh ≥ 30 cm were identified and recorded. Soil properties were evaluated from ten soil samples collected randomly in each of the surveyed plots in the forest. Soil samples were obtained with a soil drill at a root depth of 15-50 cm. Twenty-five soil properties were studied Principal Component Analysis (PCA) was used to study the soil physico-chemical properties that influenced forest tree species growth. The results of the survey revealed a great diversity of tree species in the forests, as 81 species belonging to 34 families were recorded. The tree species dbh and height ranged from 30 – 396.3 cm and 13.2 – 69.4 m, respectively. Soil physicochemical properties revealed varied presence of the twenty five soil properties studied in the forest. PCA revealed that the soil in the CRNP, Oban had eleven (11) fundamental properties (total nitrogen (TN), Available Phosphorus (AVP), Sodium (Na^+), Potassium (K), Boron, Manganese (Mn), exchangeable cation (EC), Clay (soil texture), magnesium (Mg), Zinc (Zn) and Silicon (Si)) that influence tree species growth. Our findings will provide conservationist, ecologist and forest managers the ecological data necessary for sustainable forest management in the CRNP, Nigeria.

keywords: Cross River National Park, Oban Division, Tree species diameter and height, Soil physicochemical properties, Principal Component Analysis.

ECOABR023

MICROBIAL BASED WEED MANAGEMENT STRATEGIES: AN EMERGING INNOVATIVE STRATEGY FOR LARGE SCALE HORTICULTURAL CROPS PRODUCTION

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ABSTRACT

Alternative weed management strategies are needed to expand the capability of weed control as weed pressures continue to limit optimum yield, and as the use of synthetic chemical herbicides for weed control becomes more restricted. Biological control of weeds is based on the premise that biotic and abiotic factors influence the distribution, abundance, and competitive abilities of plant species (especially invasive plants). Biological control is one alternative means of suppressing weed growth and establishment. More than 100 microorganisms have been identified as having the potential for weed biocontrol. There are, however, a number of problems with using these agents that must be solved, including limited host spectrum, lack of consistency across environments, and slow or inadequate weed suppression. It has been shown that soil microorganisms are capable of suppressing weeds in the field (indigenous plant pathogens isolated from weeds are cultured to produce the large numbers of infective propagules). It is imperative to develop an understanding of these soil microbes and their ecology so that they may be used to benefit agriculture, especially for weed management. Hence this study highlights the advances in the field of weed management and their efficiency in field nursery production.

Keywords: Microbial-based, Weed Management, Crop production, Horticulture.

A MYCOLOGICAL EVALUATION OF WETLAND DIVERSITY, BIOGEOCHEMICAL ACTIVITIES AND ECOLOGICAL CONSEQUENCES

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ABSTRACT

Wetlands are lands where saturation with water is a dormant factor. Wetlands can be characterized by their hydrology, hydrophytic vegetation and hydric soils. The main wetland types are swamp, marsh, bog and fen based on the soil type and plant life found there. Popular wetlands in Nigeria include the Sokoto-Rima wetland, Komadugu Yobe wetland, lake chad wetland, upper Niger Lake wetland, Kanji Lake wetland, middle Niger (Lokoja wetlands) and Jebba wetlands. Wetlands are highly productive ecosystems with abundant carbon storage which play a critical role in the global carbon cycle. Wetlands possess an array of aquatic organisms including fungi which play an important role in organic matter recycling and food web dynamics. Fungi diversity in wetland include aquatic hyphomycetes, arbuscular mycorrhiza , lichens, saprophytic fungi and water mold. Fungi found in wetland have very absorbent hyphae which helps them absorb water, possesses the ability to tolerate fluctuating water levels, add, absorb and store nutrient, unique mode of nutrition, possession of aerenchyma, can survive anoxic and toxic environmental conditions. Furthermore, wetland fungi play important roles by the formation of symbiotic relationships with other organisms, provide habitat for other organisms, water quality control, provide food for other organisms and mineralization. The diversity of wetland fungi is astounding, and they play a vital role in the functioning of wetland ecosystems.

Keywords: Mycological diversity, biogeochemical potential, ecological impacts, wetlands, Wetland fungi.

ECOABR025

THE EVALUATION OF SUSPENDED PARTICULATE MATTER (SPM) IN SOME COMMUNITIES ASSOCIATED WITH ARTISANAL REFINERIES IN BAYELSA STATE, NIGERIA

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ABSTRACT

The growth of artisanal refineries in Nigeria's Niger Delta is posing a significant public health risk due to the release of toxic fumes with suspended particulate matter (SPM). This study evaluated the concentration of SPM, which was measured at six locations, including a control station, using a digital portable hand-held meter (AEROCET-513, Metone instrument). Results showed that the SPM ranges were: PM1.0 (17.68–28.99 µg/m^3), PM2.5 (23.48–39.69 µg/m^3), PM4.0 (35.84 –58.18 µg/m^3), PM7.0 (45.63–78.57 µg/m^3), PM10 (69.16–117.67 µg/m^3), and Total Suspended Particulate Matter (TSP) ranging from 171.37–257.52 µg/m3. Compared to all sites in the study area (L1–L5), the control site (LX) had the lowest concentration of particulate matter ($p<0.05$). The study found that artisanal refineries in the Niger Delta emit higher levels of particulate matter (SPM), exceeding WHO and national air quality standards. These emissions are attributed to anthropogenic activities aided by some meteorological indicators. The study calls for policies to prevent detrimental anthropogenic activities and encourage modular refineries to create employment opportunities for the youth in the Niger Delta; and which require the input of the government, community leaders, regulators, and all stakeholders.

Keywords: Artisanal refineries, Suspended particulate matter, Air quality, Pollution, Crude oil.

ECOABR026

ASSESSMENT OF SOIL POTENTIAL EFFICIENCY FOR WETLAND UTILIZATION IN WUSHISHI LOCAL GOVERNMENT AREA OF NIGER STATE, NIGERIA

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ABSTRACT

This study focused the soil potential efficiency of wetland utilization in Wushishi local government area of Niger State with the following aims, i. to achieve potential capability of soil regarding crop production in the wetland, ii. quantify and evaluate magnitude of wetland soil potentials using Remote sensing data and laboratory analysis, and iii. compare heterogeneous nutrient data to predict the soil capability and potentials for crop production. The study utilized the potential of laboratory test and GIS integration of heterogeneous nutrient data to effectively state and predict the soil capability and potentials in order to ensure improvement in crop production. The findings show that there are more wet years than dry years which indicates about 13.39% annual increment of land utilization with normal annual precipitation distribution. The statistical analysis showed an annual increasing trend of 0.1339 with an R2 value of 0.33. It was also discovered that farming activities in the area increased from 37.12% in 1989 to 48.90% in 2022. Only Maito area is cultivated by subsistence farmers. The study concludes that Zungeru camp, Tunga Kawo and Wushishi areas have suitable soil potential for farming, ranging from 58.0 – 97.0 with soil/water potential pH of 7-10 and 6-9 moles respectively. This indicates that the area is not acidic but suitable for cultivation of cereal crops like rice, maize and grains. The topographic setting of Bankogi area which is steep-sloped, lacks vegetation and is currently not suitable for any agricultural activities. The study, therefore, recommends that farmers should be sensitized on wetland farming benefits and should be encouraged to form farming associations so as to attract soft loan from the banks and philanthropies. More also fields of land should be set aside to practice hybrid cultivation in the communities.

Keywords: heterogeneous nutrients, soil capability, silt, sandy soils.

ECOABR028

ENHANCING HOUSEHOLD DIETARY DIVERSITY THROUGH THE ADOPTION OF CLIMATE-SMART AGRICULTURAL PRACTICES: EVIDENCE FROM NIGERIA

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ABSTRACT

The paranoid belief that climate change will gradually reduce the ability of the world to meet the demand for food serves as the rationale for Nigerian smallholder farmers' advocacy of climate-smart agriculture (CSA) techniques. The study investigates the effects of CSA practice on the food security status of rural farming households in Nigeria. A multi-stage sampling technique was employed in selecting 480 rural farming households across three selected states from Southwestern, Nigeria. Data were analyzed using descriptive and inferential statistics. Obtained results showed that 59.79% of the respondents were food insecure while severe and depth of food insecure among the farming households were 0.0711 and 0.1913 respectively. The result of the household dietary diversity score revealed the diverse consumption-ability of the respondents and the contributions of CSA practice in their farming system. This implies that households engaged in climate-smart farming are more likely to achieve higher levels of food consumption score, dietary diversity, and food security. The probit regression revealed that the food security status among rural farming households was significantly influenced by household heads' gender, farm size, and contact with extension agents as well as adopted CSA practices such as crop diversification, agroforestry, and use of Fadama land for agricultural activities. This research concludes that CSA lowered the probability of food insecurity among rural farming households in Nigeria. Accordingly, the study suggests that the government and the key players should encourage the use of CSA practices in order to ensure agricultural sustainability and food security in agrarian communities by reducing the impact of climate change.

Keywords: Climate variability; Climate-Smart Agriculture; Crop diversification; Food security; Regression; Sustainability.

ECOABR029

INVASIVE PLANT SPECIES: ECOLOGICAL IMPLICATIONS AND HEALTH RISKS

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ABSTRACT

Invasive plant species pose significant ecological challenges worldwide, with far-reaching consequences for both native ecosystems and human populations. Invasive plant species affect native ecosystems by altering disturbance regimes, outcompeting native flora, and lacking natural predators or pathogens. These disruptions lead to habitat degradation, species displacement, and loss of genetic diversity, ultimately compromising ecosystem resilience and stability. The impacts of invasive plants on humans are numerous. Economically, they can reduce agricultural production, raise management costs, and undermine infrastructural integrity by affecting streams and structures. Furthermore, certain invasive plants like *Eichhornia crassipes* (Water hyacinth) pose health risks, either through allergenic pollen, toxic compounds, or as vectors for disease transmission. Additionally, invasive species can alter landscapes, diminishing the aesthetic value of natural areas and affecting tourism and recreational activities. To tackle these challenges, a multifaceted approach is necessary. Integrated management tactics that include mechanical, chemical, and biological control measures are frequently successful in controlling invasive plant populations. Prevention through early detection and rapid response initiatives is also crucial for controlling the spread of invasive species. This review further suggests the raising of public awareness and involvement which might help to mobilise resources and support for invasive species management activities.

Keywords: Invasive plants, Ecosystem health, Alien plants.

ECOABR030

SEASONAL VARIATION OF HEAVY METAL INUNDATION OF *RHIZOPHORA RACEMOSA* DOMINATED NIGER DELTA MANGROVE ECOSYSTEM IN SOUTH SOUTH NIGERIA

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ABSTRACT

The seasonal variation in heavy metal inundation of four study stations of *Rhizophora racemosa* dominated mangrove forest across four Local Government Areas of Rivers State namely Khana (Kono), Gokana (Bomu), Ogu/Bolo (Ogu) and Port Harcourt City (Borokiri) was evaluated in this study using the completely randomized design. Soil samples were randomly collected in the dry and wet seasons across the designated stations and analyzed for Cr, Ni, Cd, Zn and Pb using the atomic absorption spectrophotometer. The results of the study showed seasonal difference in the concentrations of the studied metals across the stations. Overall, the study revealed a lower concentration of heavy metals at the wet season with a mean, standard deviation and coefficient of variation of 0.523 mg/kg, 0.210 and 40.15%, respectively when compared with the dry season input which showed 0.572 mg/kg, 0.280 and 48.95%. The study therefore indicates high input of heavy metals into the mangrove ecosystem at dry season than wet Season. Seasonal monitoring of heavy metal pollutants into the mangrove forest would enhance pollution control and overall ecosystem protection.

Keywords: Heavy metal, Mangrove forest, *Rhizophora racemose*, Ecosystem protection, Pollution control

ECOABR031

EXPLORING WEEDY GRASS DIVERSITY WITHIN RICE FIELDS: A CASE STUDY OF HADEJIA- NGURU WETLAND FLOOD PLAIN

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ABSTRACT

Rice fields are complex agroecosystems harboring a diverse array of plant species, including various weedy grasses. Understanding the diversity and distribution patterns of these weedy grasses within rice fields is crucial for effective weed management strategies and sustainable rice cultivation. This study aims to investigate the diversity of weedy grass species in Hadejia-Nguru wetland flood plain and assess their spatial distribution patterns for effective weed management strategies, which can enhance crop productivity and sustainability. Field surveys were conducted in a representative rice field located within Hadejia Nguru wetland flood plain during the 2023-2024 growing seasons. A systematic sampling approach was employed to collect weedy grass specimens from different microhabitats within the rice fields. Taxonomic identification and classification were performed using standard botanical keys and expert consultation. Preliminary findings indicate a notable diversity of weedy grass species within the rice field, with 16 genera and 26 distinct taxa were identified. These species exhibit varying spatial distributions, influenced by factors such as water availability, soil characteristics, and management practices. Some species show preference for specific microhabitats within the rice field, while others exhibit a more widespread distribution. Understanding the diversity and distribution patterns of weedy grasses within rice fields is essential for devising integrated weed management strategies that minimize crop yield losses while promoting environmental sustainability. Further research is needed to elucidate the ecological interactions among weedy grass species and their impacts on rice production systems.

Keywords: weedy grasses, rice fields, diversity, spatial distribution, weed management, agroecosystems.

APPLICATION OF BIOCHAR FOR BIOREMEDIATION OF POLLUTED SOILS RECEIVING AUTO-MECHANIC WASTE IN MINNA, NIGER STATE

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ABSTRACT

Agricultural soil polluted by heavy metals in an auto mechanic site is a common occurrence in most developing countries. This has been shown to have harmful effects on the soil, environment and human beings at large. Bioremediation technology can be an alternative green technology for remediating such heavy metals in the soil. This study examined the bioremediation potential of two activated carbon (Biochar); Coconut shell biochar and Sugarcane bagasse over a 40-day period. Seven treatment formulations (100g of coconutshell biochar (AIX), 50g of coconutshell biochar (A2X), 100g of sugarcane bagasse (B1X), 50 g of sugarcane Bagasse (B2X), 50 g coconutshell +50 g sugarcane bagasse (C1X), 100 g Sugarcane+ 50g coconutshell Biochar (C2X) and 100g coconutshell + 50 g sugarcane biochar (C3X) were used to evaluate agricultural soils receiving auto mechanic waste in Angwan Daji in Bosso local government area of Minna, Niger State. Soil samples were collected at different sampling points of the site to analysed the physiochemical properties of the soil and some selected heavy metals that includes Lead (Pb), Iron (Fe) and Zinc (Zn). The experiment was replicated three times in a Completely Randomized Blocked Design (RCBD). The concentration of Pb, Fe and Zn from the soil samples taken from the sites were 24.24 mg/kg,1359 mg/kg and 168.30 mg/kg respectively and were found to be relatively high compared to the control sample taken 100 meters away from the Auto mechanic site. A significant Bioremediation process was achieved after 40 days of the experiment. The result showed that A1X (100g of Coconut shell Biochar) gave the best statistically significant difference in the Remediation of Heavy metal (Pb, Fe and Zn) as compared to other treatments. The study clearly demonstrated that activated carbon from coconut shell can be used to significantly enhance or increase the rate of remediation.

Keywords: Soil Pollution, Heavy metals, Bioremediation, Auto-mechanic waste, Biochar.

ECOABR033

PLANKTON COMMUNITY STRUCTURE IN RELATION TO WATER QUALITY OF ORIA RIVER, DELTA STATE, NIGERIA

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ABSTRACT

The plankton community and water quality assessment of the Ethiope River Oria, Delta State, Nigeria were studied fortnightly to comprehend the dynamics and community structure of plankton between June and August 2023, Standard procedures were employed to examine the physicochemical characteristics of water: Temperature ranged from 28.5°C to 30.5°C; turbidity from 40.50±0.21 to 51.20±1.27 (NTU); dissolved oxygen (DO): 3.80±0.01 mg/l to 7.85±0.35 mg/l; alkalinity from 1.95±0.20 mg/l to 4.17±0.80 mg/l; Ammonia: 0.08±0.01 mg/l to 2.43±0.02 mg/l; nitrate: 2.04 ±1.08 mg/l 3.62±0.31 mg/l; and phosphate ranged from 2.33±1.24 mg/l to 4.54±0.52 mg/l. DO, nitrate, and phosphate were found to be within the WHO-recommended range. Manganese concentrations were high upstream (10.00±0.57 mg/l) and downstream (10.85±0.64 mg/l). For phytoplankton, ten (10) families were identified; *Gyrosigma* sp. were the most dominant upstream while *Aulacoseirs* sp. is the most dominant downstream. *Aulacoseirs* sp. presence is suggestive of a possible deterioration in water quality. Throughout the investigation, rotifers were entirely absent upstream, whereas copepods, cladocerans, and rotifers were observed in abundance downstream. The plankton community is richer downstream than upstream (S=0.59 upstream and 0.66 downstream). The Shannon diversity index, on the other hand, showed 0.99 upstream and 1.09 downstream indicating higher diversity in downstream than upstream. Human pressures can have an impact on plankton abundance, thus it's important to monitor native waterbodies and manage them with awareness campaigns for the local population.

Keywords: Community structure, Biodiversity, Bio-indicator, Plankton, Water quality.

ECOABR034

THREATS TO 11 RAMSAR-LISTED SITES AND OTHER WETLANDS IN NIGERIA AND POSSIBLE WAYS TO SALVAGE THEM: A CONCISE REVIEW

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ABSTRACT

Nigeria is uniquely blessed with wetlands of freshwater and coastal saline waters, some of which have been enlisted among the Ramsar sites. The surface wetland water alone accounts for majority (97%) of water supply for various uses. The value and resources of the Nigerian freshwater wetlands could produce about 510,000 tons of fish, wetland resources for vertebrates worth over 14 reptile species, 7 mammal species, 5 amphibian species, about 72 bird species and over 200 species of fish. This paper reviews threats to the 11 Ramsar-listed sites and other wetlands of Nigeria. The threats include overexploitation, poaching, irrigated agriculture development, recession of lakes due to human and climatic influences, constructions of dams, bio-invasions, siltation, oil spillage, militancy and insecurity. It aims to raise awareness and bring to the attention of Policymakers and other stakeholders, the need to conserve these precious Ecosystems so that they continue to provide their vital services for human benefits. The recommendations put forward as possible ways to salvage the wetlands include; funding researches to investigate issues affecting flora and fauna of the wetlands, eliminate bio-invasion, formulate and implement policies forbidding unlawful encroachment of wetlands in Nigeria and imposing fines and penalties on offenders.

Keywords: Ramsar sites**,** Recession of lake, Environmental threats, Wetlands, Biodiversity protection, Ecosystem services.

ECOABBRO35

EFFECTS OF BALLAST WATER ON WATER-PRIMEROSE -*Ludwigia abyssinica* A. RICH. (FAMILY: ONAGRACEAE)

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ABSTRACT

Effects of ballast water on the chlorophyll content, plant height, longest root length, stem girth and leaf number of *Ludwigia abyssinica* was investigated. Ballast water was obtained from MT OCEANA vessel at Lagos seaport, Nigeria. *L. abyssinica* and river water were collected from Ikpoba River, Benin City, Nigeria. Ballast water was analysed using standard procedures to determine its physical and chemical properties. Different concentrations of ballast water were prepared by mixing the river water and the ballast to produce concentrations of 5 %, 10 %, 25 %, 50 % and 75%, ballast water only served as 100 %concentration while 0 % concentration served as control. The experiment was set up in the screenhouse of Department of Plant Biology and Biotechnology, University of Benin, Nigeria. Observations were recorded for 15 days. The CCI of *L. abyssinica* at different ballast concentration was measured using the Chlorophyll Content Meter (CCM-200 plus); the plant height and root length were measured using a ruler; the stem girth was measured using a digital Vernier caliper while normal counting was done for leaf number. Analysis of variance using Duncan's multiple range statistics to separate means showed that 50 %, 75 % and 100 % ballast water concentrations produced significant debilitating effects on chlorophyll contents, plant heights, longest root lengths, stem girths and number of leaves of *L. abyssinica* ($P < 0.05$) when compared to the lower concentrations of ballast water. The results of this experiment showed that higher concentrations of ballast water had significant reduction effects on the measured physiological parameters of *L. abyssinica.*

Keywords: Ballast water, Chlorophyll content, *Ludwigia. Abyssinica,* Onagraceae, Plant biology

ECOABR036

DIVERSITY AND COMPOSITION OF SOIL SEED BANKS IN SELECTED MAIN ROADSIDES IN PORT HARCOURT METROPOLIS, NIGERIA.

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ABSTRACT

Soil seed banks consist of viable seeds in the soil that have the ability of resorting adult plants. Its role is very vital in ecosystem. To species diversity in soil seed banks of four major roadsides (Aba Road, East/West Road, Ikwerre Road and NTA Road) in Obio/Akpor Local Government Area and a control (Ikwerrengwo) in Etche Local Government Area in Port Harcourt, Rivers State, Nigeria. Soil samples were obtained using systematic sampling technique at different soil depths (0-5cm, 5-10cm and 10-15cm) with the aid of a soil auger. Seedling emergence method was employed in analyzing the soil seed bank. Shannon-Weiner diversity index was used to determine the species diversity and evenness. A total number of twenty five species belonging to fourteen families were identified from the soil seed banks. Species such as *Oldenlandia* species, *Agerantum comyzoides*, *Pennisetum* species, *Elusine indica*, *Talinum triangulare* and *Mimosa* species were common at both the experimental and control sites. The soil seed banks studied revealed that the experimental and control sites were characterized by more grasses, more herbs and fewer trees and shrub. The number of species at the control site were more than the experimental sites. Thus, vehicular emission and man's disturbance of roadside soils has changed the diversity and composition of roadside soils.

Keywords: Soil Seed Bank, Metropolitan roads, Ruderals, Species Diversity, Species composition.

ECOABR037

COMPETITIVE ABILITY OF *Mimosa diplotricha* C. Wright IN A 2-SPECIES REPLACEMENT SERIES COMBINATION WITH *Tithonia diversifolia* (Hemsl.) A. Gray.

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ABSTRACT

Invasive plants are usually adaptable to various ecological conditions which promote their establishment and spread to replace native species. *Mimosa diplotricha* and *Tithonia diversifolia* are two established invasive plants in Nigeria. Competitive interaction study between *Mimosa diplotricha* and *Tithonia diversifolia* was carried out to investigate conditions by which the two invasive plants replace one another or co-exist in the ecosystem. The competitive ability of *Mimosa diplotricha* relative to *Tithonia diversifolia* in a 2-species replacement series experiment at four total densities in pure stands (22, 44, 88, 176 plants/m^2) and at three total densities in equi-proportion mixture (44, 88, 176 plants/m^2) was studied. Relative competitive ability indices [Relative Yield (RY) and Relative Yield Total (RYT)] were determined from plant dry weight, and the replacement series diagrams were drawn. Where RY>0.5=aggressor, RY<0.5=sub-ordinate, RY~1=competition, RYT<1=mutual antagonism, RYT~1=competition and RYT>1=synergistic relationship. The RY for *M. diplotricha* and *T. diversifolia* increased with increasing plant density with a range of 0.7-0.9 and 0.6-0.8, respectively. The RYT at all densities ranged from 1.29-1.70 and were significantly greater than one, thus indicating a synergistic relationship between *M. diplotricha* and *T. diversifolia*. The study showed that *Mimosa diplotricha* grew aggressively longer in mixed culture than in monoculture, which could be due to the plant's heliophytic response to shade being cast on it by the associated *Tithonia diversifolia*, which also formed stakes on which *Mimosa diplotricha* climbed to overcome the shade. This may explain the survival of *Mimosa diplotricha* in ecosystems infested with *Tithonia diversifolia*.

Keywords: Competition, Invasive plants, Relative yield, Heliophytic response.