NIU Journal of

Climate Justice and Governance

Nexus International University, Uganda.

Published in June, 2026

ISSN: 3007-1828 (Print)

ISSN: 3007-1836 (Online)

Published by:

Nexus International University,
Kampala, Uganda.

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Nexus International University ISSN: *3007-1828;* 12(1): 3

Editorial

This edition of NIU *Journal of Climate Justice and Governance* touches on as Climate Finance Improvement, Access to Climate Change Information, Climate–Microbiome Dynamics, Urban Gentrification and Housing Affordability.

One of the papers, in this issue, argues that climate change information awareness levels were generally high among palm oil farmers in Delta State of Nigeria, with extension agents, the internet, radio, and mobile phones ranking prominently in awareness and preference. In other words, while oil palm farmers in Delta State demonstrate moderate awareness and diverse information access channels, reliance on informal networks persists due to limited institutional outreach. It therefore, recommends adopting Rwandan best practices in enhancing government accreditation to global funds, improving training and institutional capacity, and creating an enabling environment characterized by political stability and security.

Another paper also reveals that lack of finance, inability to create a direct access entity (DAE), lack of institutional capacity, and enabling environment for the private-public partnership are impediments to access global climate finance for resilient environment in Nigeria. The paper therefore, recommends that the management must do everything within its power to manage labour movement in the organization through employee engagement, ensuring employee welfare, working conditions and timely compensation and other benefits so that trade unionism does not turn to be a menace to organizational stability.

On the whole, this edition of *NIU Climate Justice and Governance* features many empirical and theoretical based articles which can be of great benefit to every reader.

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June, 2026.

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Nexus International University ISSN: *3007-1828;* 12(1): 5-16

Strengthening Climate Finance in Nigeria: Lessons from Rwanda

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Abstract. Climate finance involves allocating funds from local, national, and international sources to support actions for mitigating, adapting, and building resilience to climate change. As a developing nation, Nigeria grapples with addressing challenges in meeting its climate objectives as spelt out in the United Nations Framework Convention on Climate Change (UNFCCC), the Paris Agreement and its Nationally Determined Contributions (NDCs). This paper investigates the problems of accessing global climate fund and achieving sustainable environment in Nigeria. The increasing climate risks—such as flooding, rising sea levels, record temperatures, and prolonged droughts—underline the urgency for access to global climate finance. The paper found a lack of finance, inability to create a direct access entity (DAE), lack of institutional capacity, and enabling environment for the private-public partnership as impediments to access global climate finance for resilient environment. As the largest economy in Africa, Nigeria stands at a crucial juncture where access to global climate finance can help drive sustainability. Increased access to finance is therefore essential to reach development goals and climate targets. It argues against sole reliance on global finance but harnessing domestic funds especially with private-public partnerships to achieve its NDCs. The paper recommends adopting Rwandan best practices in enhancing government accreditation to global funds, improving training and institutional capacity, and creating an enabling environment characterized by political stability and security. Ultimately, the paper argues that inclusive finance is the most effective way to distribute climate resources to the grassroots level, enabling a just transition and comprehensive global climate action.

Keywords: Climate Finance, Climate Risks, Sustainable Environment, Direct Access, Domestic Fund.

1. Introduction

Since the COVID-19, Climate change has been considered the single greatest challenge facing humanity and the biggest threat to all life on Earth. The Sixth Assessment Report (AR6) of the Intergovernmental Panel on Climate Change (IPCC) states that the world is currently not on track to keep the 1.5% limit agreed upon in Paris and cut global emissions by 43% in this decade. Climate change, driven by the emission of greenhouse gases (GHGs), poses an urgent challenge, particularly to the poorest communities, which are likely to be hit hardest by its worsening impact (IPCC, 2022).

Globally, the urban portion of national emissions rose from 56% in 2000 to 62% in 2015, a six-percentage increase. The percentage of urban emissions rose from 28% to 38% in Africa, from 46% to 54% in Asia and the Pacific, from 62% to 72% in developed nations, from 57% to 62% in Eastern Europe and West Central Asia, from 55% to 66% in Latin America and the Caribbean, and from 68% to 69% in the Middle East between 2000 and 2015 (IPCC, 2022). Although Africa is not directly responsible for climate change, it is warming faster than the other continents. The 2001 Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) showed that the frequency and intensity of drought seem to have worsened in parts of Africa (United Nations Fact Sheet on Climate Change, 2006). Also, the IPCC AR6 indicates that vulnerable communities that contributed the least to current climate change are disproportionately affected (IPCC, 2023. Impacts of

climate change faced by Africa include increased drought and floods, leading to a decrease in food production, floods, and inundation of its coastal zones and deltas, the spread of diseases like waterborne diseases and risk of malaria, and changes in natural ecosystems and loss of biodiversity.

Global warming is expected to increase due to continued greenhouse gas emissions, with the best estimate putting it around 1.5^0C in the future. Africa is warming faster than the rest of the world and if left unabated, climate change will continue to have adverse impacts on African economies and societies and hampering economic growth and wellbeing (United Nations Fact Sheet on Climate Change, 2006). According to the International Energy Agency (2021) achieving net-zero emissions requires an annual financing of $5 trillion by 2030 to be sustained until 2050. Despite housing an estimated 40% of the world's renewable energy resources, Africa has achieved only $60 billion or two percent of $3 trillion in renewable energy investments in the last decade (African Exponent, 2025).

Although shifting from fossil fuels to cleaner energy has negative implications on petro-dependent states, especially Nigeria, the Nigerian government has launched an Energy Transition Plan (ETP) to accentuate its commitment to achieving Net Zero emissions by 2060. Nigeria seeks to invest an additional $410 billion in funding by 2060 and has defined incremental funding of $10 billion per annum to achieve this goal. However, the total fund required to reach Net Zero emissions by 2060 is $1.9 trillion (Nigeria Energy Transition Plan, 2022). This is significantly unrealistic to a country whose debt status is increasingly a cause for alarm, spending over 80% of its revenue servicing debt, leaving only 20% of its revenue for vital social services and development (Stiftung, 2023). An analysis by the Climate Policy Initiative (CPI) for Africa in 2021/2022 showed that 79% of Nigeria's international climate finance was provided as debt (concessional and non-concessionary terms) (Climate Policy Initiative, 2024). Grant or equity financial investment or innovative financing instruments can lessen the burden of debt distress and unlock the opportunities of private sector investment to solve the climate crisis in Nigeria.

Inclusive climate financing has occupied the global climate discussions, demanding urgent and concerted action from all nations to lower emissions and reduce the concentration of greenhouse gases (GHGs) in the atmosphere. Many stakeholders argue that "the global financial system must be a part of the climate solution." The principle of equity, common but differentiated responsibilities, and respective capabilities are set out in the UNFCCC and the Paris Agreement. However, the issue of access to funding remains unresolved. Developing countries, often the most vulnerable, are desperately struggling to deal with a climate crisis caused by developed countries. This necessitates the call for the global financial system to be part of the climate solution, channelling climate finance into the hands of those most affected by climate change.

Countries agreed to the obligation to provide financial support under Article 9 of the Paris Agreement that the developed country Parties shall provide financial resources to assist developing country Parties for both mitigation and adaptation in continuation of their existing obligations under the Convention. As part of a global effort, developed country Parties are to continue to take the lead in mobilising climate finance from different sources, instruments, and channels, representing a progression beyond previous efforts on climate mitigation and adaptation (Article 9 (3) UNFCCC).

The above notwithstanding, different countries have Nationally Determined Contributions where net-zero targets are set. In line with international requirements, Nigeria enacted the Climate Change Act (CCA) 2021, and other policies on Nationally Determined Contributions and Energy Transition Plan. Having been ranked as one of the most vulnerable countries to climate change, Nigeria has taken action to reduce GHG emissions and mitigate climate change. Where fully implemented, the CCA will ensure adequate energy for sustainable rapid socio-economic development, develop an integral agricultural intervention plan to reduce vulnerability of the sector to climate change, helping to enhance food security and achieve poverty reduction, give way to improved individual health and environmental outcomes; lead to sustainable economic development through innovative investments opportunities, et cetera. However, it is important to state here that the enactment of the law is different from its implementation, as there are challenges to implementing these noble ideas provided in the CCA; these will be discussed in this article in due time.

As one of Africa's major economies and a growing GHG emitter, Nigeria is the fourth largest GHG emitter in Africa. Despite contributing only 0.23% of global cumulative CO2 emissions, Nigeria is already facing significant consequences of climate change. For instance, in 2012, the northeastern part of Nigeria experienced a devastating combination of extreme drought and extensive flooding that impacted nearly

the entire nation, resulting in displacement of 2 million people and approximately $17 billion in damages (Federal Republic of Nigeria, 2013). The increasing frequency of floods, droughts, rising ocean temperatures, alterations in snowfall and rainfall patterns, intense rainstorms, and heavy precipitation, alongside declining soil nutrients and deteriorating environmental quality, clearly highlight the significant threats climate change poses to food security and nutritional health in Nigeria (Dauda, 2023).

The years 2015, 2016 2017 and 2018 witnessed displacement of 100,000, 92,000, 250,000 and 1.9 peoples respectively, a critical situation occasioned by flooding (WHO, 2020). Climate change poses significant challenges to food security in Nigeria, reflecting broader issues faced across Africa. The alterations in climatic conditions, such as changes in rainfall patterns and increased temperatures, have severely impacted agricultural productivity.
As a result, Nigeria has experienced disruptions in planting and harvesting seasons, leading to crop scarcity and rising food prices, exacerbating food insecurity. Flooding caused by rising sea levels and intense rainfall in regions like the South-South and South-East has resulted in the loss of farmland and biodiversity, disrupting agricultural activities. These challenges are compounded by the need for enhanced irrigation systems, as erratic precipitation patterns create inconsistencies in water supply. Increased irrigation demands raise production costs, making it difficult for many farmers to sustain their livelihoods, further contributing to potential food shortages. These issues underscore the intricate relationship between climate change and climate financing, highlighting the broader implications for building a resilient economy.

Addressing these challenges requires comprehensive strategies that incorporate sustainable agricultural practices, climate resilience measures, and investment in renewable energy to mitigate the impacts of climate change effectively. Transitioning from energy production and consumption of fossil fuels to cleaner energy sources is important in achieving more sustainable energy consumption and usage and avoiding the clear adverse impact on use of fossil fuels. Embarking upon adequate climate finance today and effectively focusing it on mitigation and adaptation to building resilience to climate change will determine whether growth is sustainable and equitable for the rest of this century and children unborn.

Nigeria like other developing countries lack finance to transition to green energy and this remains the greatest barrier to transitioning to green energy. A revised Nationally Determined Contribution (NDC) was achieved at the run up to COP 26 with investment action to the value of $177 billion, while the nation's Energy Transition Plan (ETP) which anchored net-zero carbon pledge by 2060 has an investment of $410 billion by 2060 for the country to meet its target on energy transition. However, research has shown that a total of $92 billion investment is required to achieve sustainable development devoid of climate vulnerability up to 2030. This is quite impossible considering the rising debt of Nigeria, lack of simple centralised mechanism to access international fund, lack of institutional capacity and technical know-how in attracting international climate finance, which is equally exacerbated by government's inability to mop up local and national finance by engaging the public-private to co-finance projects and leverage additional resources to strengthen climate finance for climate initiatives.

Adequate funding to achieve low emissions, resilient livelihoods, and climate-resilient growth can provide the much-needed opportunity to ensure the infrastructure and ecosystems necessary for climate mitigation and adaptation. Therefore, the quality and quantity of climate finance are crucial. Despite the benefits derived from greenhouse gases such as oil and gas, support from both the private and public sectors is essential to addressing Nigeria's greenhouse gas challenges.

According to the World Bank Group, Nigeria's overdependence on climate-sensitive industries (agriculture, forestry, oil, and gas extraction) and climate change inaction could cost it between 6% and 30% of GDP by 2050, equivalent to a loss of $100-460 billion (World Bank Group, 2020). Inclusive finance, which encompasses both national and international sources of finance, therefore can be the most effective way to distribute climate finance to the grassroots level, enabling a just transition and truly global climate action for sustainable environment. There is a need for legal frameworks that align with contemporary climate finance mechanisms and international agreements. To overcome sustainability risks, the government should ensure sovereign sources of finance in collaboration with the private sector, regional and domestic financial institutions to prevent overreliance on international funding.

This research evaluates climate financing and the difficulty in accessing global climate finance in Nigeria. Understanding the method of accessing global climate finance is critical for sustaining climate finance drive in Nigeria. Furthermore, the academic literature on climate finance fails to cover problems of difficulties in accessing global climate finance. The

lack of institutional capacity, technical know-how, to lack of financeable projects affect Nigeria's access to climate finance. The research therefore undertakes a climate-finance analysis of the importance of access to global climate finance and challenges in accessing them in Nigeria. The research is in five parts including this introduction. The second part identifies the concepts of climate finance, analysing both domestic and international forms of finance. The third part identifies the legal framework in Nigeria while establishing the important institution responsible for climate change, carbon budget and its limit on emissions. Part four deals with climate financing proper in Nigeria, challenges in accessing global fund with Rwandan best practices and finally, the conclusion.

2. Key Definitions

2.1 What is Climate Finance?

There is no universal definition of climate finance. The UNFCCC which ordinarily would have provided a definite definition fails giving a leeway to multiple definitions by data collectors and aggregators although with common elements. This notwithstanding, climate finance has been defined as finance that "aims at reducing emissions and enhancing sinks of greenhouse gases and aims at reducing vulnerability of, and maintaining and increasing the resilience of, human and ecological systems to negative climate change impacts." To Soubeyran and Macquarie, climate finance generally refers to finance for activities aiming to mitigate or adapt to the impacts of climate change (Soubeyran and Macquarie, 2023).

Oftentimes, climate finance is used interchangeably with the related and overlapping concepts of green finance, sustainable finance, and low-carbon finance. It is generally referred to as local, national, or transnational financing, drawn from public, private and alternative sources of financing, that seeks to support mitigation and adaptation activities that will address climate change. This definition highlights the various sources of climate finance, extending them the 1992 agreement to include both local and national sources. The above definitions of climate finance represent the flow of funds, or channeling funds to activities, programmes and projects geared towards addressing climate change: for mitigation and adaptation in all economic sectors.

To international diplomacy on climate change, climate finance implies "new and additional financial resources" provided by developed countries to developing countries to meet the full and incremental costs of climate change and decarbonisation. The definition basically excludes financial market activities like bank loans to companies or investors in private or public entities but includes finance flowing directly to assets and activities, adhering to the core economic principles of avoiding "double counting" as counting a loan from a bank to an energy utility as well as the investments in renewable energy generation made by the recipient company, using the proceeds from the loans, would mean counting finance for the same activity twice. For this study, it is necessary to adopt the definition of climate finance as finance for activities aiming to mitigate, adapt, and build resilience to the impact of climate change irrespective of its source.

2.2 Sources of Climate Financing

2.2.1 Domestic Finance

This can be subdivided into private and public Funding.

Private sector financing is a type of financing sourced domestically within a country, aimed at mitigating and adapting to climate change impacts within national boundaries (United Kingdom Nigeria Infrastructure Advisory Facility, 2024). These include funds sourced from domestic institutions such as private investors, commercial banks and domestic institutional investors, individuals not excluded. Private finance adaptation is complex despite great opportunities for private sector investment. Many potential stakeholders lack awareness of eligible climate-related projects and financial mechanisms available to them. This is a call to investment in climate adaptation, mitigation and resilience. In Nigeria, the ratio of contribution for domestic climate finance between private and public sectors is 44%:70%. There is a tendency that the private sector investment in Nigeria will thrive better if government incentives are readily available, given the estimate of private sector investment in Nigeria.

Public sector sources of financing on the other hand are typically sourced from the government of a nation or allocations by the Government of a nation. For instance, the Federal Republic of Nigeria's revenues such as taxes, fees, levies, and other funds and appropriations allocated through national budgets to tackle its NDCs. Challenges to the government's climate financing range from limited budgetary allocations, lack of adequate institutions and institutional capacity, competing government priorities, inadequate policy and regulatory framework, lack of adequate data and information on

climate finance flows and lack of political will all pose great challenges to government's funding.

2.2.2 International Finance

This is further divided into international private and international public financing.

International private financing is a type of climate financial flows that cross international borders. The aim of international climate finance is basically to support developing countries in their quest to mitigate and adapt to climate change, promote sustainable development, and achieve global climate goals as set out in the Paris Agreement. International private finance may come from a variety of sources including international organisations such as the non-concessional arm of Development Finance Institutions (DFIs) and Multilateral Development Banks (MDBs). Some of the institutions offering commercial investments in Africa are the European Investment Bank (EIB), KfW- a German Development Bank, British International Investment (formerly CDC), FMO – a Dutch Development Bank, PROPARCO- a French Development Institution, Swedfund-a Swedish Development Finance Institution, and Norfund – a Norwegian Development Finance Institution, all support sustainable development projects in Africa.

International public financing involves funds provided by international entities or bodies such as multilateral development banks (MDBs): World Bank Group (WBG), African Development Bank (AfDB), international organisations, donor countries (ODA) to support climate change mitigation and adaptation efforts in developing countries. International public climate finance primarily originates from contributions made by industrialised countries, MDBs (e.g WBGroup, AfDB, and international climate funds (e.g. Green Climate Fund (GCF), Global Environmental Facility (GEF and Adaptation Fund). This finance are part of the UNFCCC commitments by industrialised countries to developing countries.

2.3 Forms of International Climate Finance Funds

2.3.1 Green Climate Fund (GCF)

This was established by the UNFCCC in 2010 and is the biggest dedicated global climate fund to boost global response to climate change, with the aim of supporting low-emission and climate resilient project in developing countries. To access the GCF, the initiator of the project is required to submit proposals through accredited entities, for example, nationally designated authorities or international implementing entities. FONERWA is Rwandan's accredited entity which serves as a national mechanism to efficiently manage and mobilise climate finance directly, bypassing intermediaries and directly securing funding from global sources as GCF, ensuring quicker and more targeted allocation of resources to climate-related projects. Rwanda has attracted significant funding from the GCF, for example in 2019, a $32.8 million grant to increase community resilience in Gicumbi District was secured by the Rwandan government, while in 2021, a $33.7 million contribution for climate adaptation in the Eastern Province including additional $15.8 million co-financing from the Rwandan government and partners was achieved (MINECOFIN, 2023). Rwanda has a strong partnership with the GCF and was the first country to receive direct access accreditation through the Ministry of Environment. Nigeria just like Rwanda ought to have access to various international sources such as the GCF and Adaptation Fund but faces the challenges of complex financing structures and limited direct access (CPI, 2024).

2.3.2. Adaptation Fund (AF)

As the name implies, AF finances adaptation projects especially in developing countries that are vulnerable to climate change impacts, that meet specific criteria such as the Least Developed Countries (LDCs). Projects like water management in drought prone areas in Ethiopia, and development of early warning systems for cyclones in Madagascar have benefited from AF.

The flow of adaptation fund to Africa is slow despite global commitments to increase adaptation finance. Between 2019 and 2020, the adaptation funding to Africa only increased to 14%, and 36% of total climate finance in 2021-2022 (CPI, 2023). The adaptation funding gap has continued to widen globally, and this is escalated by accelerating climate impacts and relatively slower growth in adaptation finance flows. Nigeria like other developing countries in Africa are hard pressed to meet their anticipated investment needs, the range of estimation to bridge the adaptation funding gap is between $130-415 billion per year by 2030 (CPI, 2023).

2.3.3 Loss and Damage Fund (LDF)

This is a new fund established under the UNFCCC providing financial support to countries that are already experiencing the impacts of climate change that are "irreversible and unavoidable." Although this fund is in its earliest stage of development, it has the

potential to provide much needed support from vulnerable countries.

2.3.4 Global Environment Facility (GEF)

GEF is the largest funder of projects that improve the global environment. This is achieved through grants and concessional funding of projects related to biodiversity, climate change mitigation, adaptation and land degradation. The AfDB and GEF collaborate in providing funding and technical expertise for African countries with limited resources to finance climate related projects. Over $400 million worth projects have been funded by both grant and private sector resources due to collaboration among these two entities (African Development Bank, 2025).

3. Legal Framework for Climate Finance in Nigeria

3.1 The International Conventions

3.1.1 The Kyoto Protocol

This is an international treaty to reduce GHG emissions, applicable specifically to six (6) GHGs: carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexaluoride. As an extension of the 1992 UNFCCC, it is based on the principle of common but differentiated responsibilities due to the socio-economic development of the countries concerned as well as the polluter pays principle. Nigeria was the 144th country to ratify the Doha amendment to the Kyoto Protocol in 2020.

3.1.2 Paris Agreement 2015

Countries agreed to the obligation to provide financial support under Article 9 of Paris Agreement 2015 thus: "Developed country Parties shall provide financial resources to assist developing country Parties with respect to both mitigation and adaptation in continuation of their existing obligations under the Convention. As part of a global effort, developed country Parties are to continue to take the lead in mobilising climate finance from a wide variety of sources, instruments and channels, representing a progression beyond previous efforts on climate mitigation and adaptation (UNFCC, Article (9) (3).

The global commitment to combat climate change was solidified by this agreement. It allowed enhanced financial flows that support developing countries in their climate actions. Developed countries reaffirmed their commitment to mobilise $100 billion per year up to 2020 to assist developing and least developed countries in their mitigation and adaptation actions, reiterating scaling up financial contributions in the nearest future.

3.1.3 1992 United Nations Framework Convention on Climate Change (UNFCCC)

The Convention on Climate in Rio de Janeiro in 1992 paved the way for global climate financing and the need to mop up financial resources from developed countries to assist the development of sustainable environment for developing countries in their efforts to limit the causes of climate change while adapting to it impacts. This includes the agreement that developed countries shall provide "new and additional financial resources" to developing countries to support meeting the full and incremental costs of climate change. This concept of climate finance is modified to include not only the support of developed countries but also private domestic sourced finance (Climate Action Network Europe, 2016). The $100 billion set in the Copenhagen Accord by developed countries, reaffirmed and adopted in Paris Agreement that "developed country Parties shall provide financial resources to assist developing country Parties with respect to both mitigation and adaptation in continuation of their existing obligations" has been bedevilled by some challenges. These challenges had not been settled even up to COP29 which ended in disagreement among member Parties in 2024.

COP29 in Baku Azerbaijan dwelt majorly on climate financing, intended to bring an end to deliberations on climate financing to reduce greenhouse effect (Chandrasekhar et al., 2024). Developing countries at COP29 set the figure for global commitments to climate finance as $1 trillion as against $200 billion by the developed countries. The negotiation ended with no consensus on a figure for climate finance, the shift away from fossil fuels or language around gender. A commitment made last year to 'transition away from fossil fuels' is also in doubt, with no mention of the phrase in the latest draft treaty text.

3.2 Domestic Laws and Policies

3.2.1 The Climate Change Act (CCA) 2021

The Climate Change Act was signed into law by the then President, Muhammadu Buhari on the of November 2021, following the Conference of Parties (COP26) in Scotland. This signalled Nigeria's commitment to climate change mitigation and energy transition as well as achieving the net zero emission target set by the President at COP26 and its

commitment to the Paris Agreement, and other standards and guidelines relevant to climate change adaptation and mitigation. The Act is a model as to how individuals and organisations interact with their natural environment to achieve sustainable development. The Climate Change Act provision is an all-inclusive, regulatory legal framework for achieving Nigeria's long-term climate goals that include net-zero carbon emissions by 2060. As a country most affected by the devastating effects of climate change, adequate climate financing and accountability will lead to a sustainable environmental achievement.

The CCA provides an institutional framework for the country to achieve its net-zero greenhouse gas emission target and enhance resilience of our economy and environment to climate change. It is applicable to both private and public entities and covers every sector.

3.2.2 National Climate Change Action Plan (the Action Plan)

Section 3 of the CCA provides for the establishment of the National Council on Climate Change (NCCC), the body responsible for implementing Nigeria's climate change action plan. A Secretariat which is an arm of the NCCC empowered under section 20 of the CCA to work in consultation with the Federal Ministry of the Environment, Budget and National Planning in formulating a long-term Action Plan every five-year to ensure that Nigeria is abreast with its international climate change commitments. This Action Plan is subject to approval by the Council and the Federal Executive Council (FEC) after being published to the general public for consultation for a period not less than eight weeks, ending 14 days before its presentation to the Council (Section 20, Climate Change Act 2021).

The Nigeria's Action Plan for climate change serves as a basis for identifying and categorising the activities aimed at guaranteeing that the national emissions profile is consistent with the carbon budget goals (section 20, Climate Change Act 2021). It establishes national goals, objectives and priorities on climate adaptation, prescribes measures and mechanisms for identifying and assessing risks, vulnerabilities and extremes of impact of climate change on vulnerable communities, populations and eco-systems; reviewing levels and trends of GHG emissions; identifying strategic areas of national infrastructure requiring climate proofing; and prescribing measures and mechanisms for achieving Nigeria's climate goals.

3.2.3 Private and Public-Private Partnership

Collaboration among private and public entities is very important in actualisation of a national climate change goals. The NCCC determines incentives for private and public entities in achieving their GHG emission reduction targets. A private entity with employees numbering 50 and above is obligated under the Act to put in place, measures to achieve the annual carbon emission reduction targets in line with the Action Plan (section 24, Climate Change Act 2021). Likewise, an entity that fails to comply with climate change mitigation and adaptation obligations is liable to penalties (section 34, Climate Change Act 2021).

3.2.4 Carbon Budget

Carbon budget is the approved quantity of GHG emissions that is acceptable over a specified period (section 35, Climate Change Act 2021). Nigeria's Carbon Budget sets legally binding limits to the amount of GHG the nation can emit over a five-year period. The Federal Ministry of Environment in consultation with the Federal Ministry of Budget and National Planning are responsible for setting carbon budget for Nigeria to ensure keeping average increases in global temperature within 2°C and pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels (section 19, Climate Change Act 2021). This responsibility includes setting the carbon budget, budgetary period, and periodically revise the carbon budget in line with Nigeria's NDCs with a view to complying with Nigeria's international obligations. The Nigeria's budget currently set annual budgets and five-year GHG emission targets to ensure the cutting of carbon emission to net-zero between 2050 – 2070. Periodic review of the carbon budget in line with the NDCs in accordance with Nigeria's international obligation are also the responsibilities of the two Ministries.

3.2.5 Climate Change Fund

Nigeria establishes a Climate Change Fund to be maintained by the NCCC (section 15, Climate Change Act 2021). The Fund comprises of sums appropriated by the National Assembly for the running of the Council; subventions, grants, donations, fees and charges for services rendered or publications made by the Council; funding from International Organisations and funds due to Nigeria for meeting her NDCs; fines and charges from private and public entities for flouting their Climate Change mitigation and adaptation obligations; carbon tax and emissions trading; and other funds as the Council may prescribe from time to time.

3.2.6 Application of Fund

The Fund is applied to defray the cost of administration of the Council and offices established under the Council; payment of emoluments, allowances and benefits of members of the Council and any committee set up or for other expenses incurred while implementing activities authorised by the Council; pay salaries, remunerations or allowances and other retirement benefits payable to the staff of the Council; the development and maintenance of any property vested in or owned by the Council; funding climate change advocacy and information dissemination; funding innovative climate change mitigation and adaptation projects, subject to the approval of the Council; defraying the fees of auditors and other expenses incurred from auditing the Council; conducting assessment of climate change impact on vulnerable communities and population; incentivising private and public entities for their efforts towards transiting to clean energy and sustaining a reduction in GHG emissions; and other expenditure in connection with any function of the Council (section 15 (2), Climate Change Act 2021).

3.3. Climate Financing in Nigeria

Climate finance has evolved significantly from the UNFCCC in 1992 to the Kyoto Protocol, the Paris Agreement, and domestic funds. This development has underscored the importance of mobilising adequate financial resources to support developing countries in their quest to mitigate and adapt to climate change. Climate finance is important in addressing the global climate change crisis. Nigeria lacks the institutional capacity to access the Global Fund. Up until now, Nigeria did not establish a direct access entity to the Global Fund which is a condition precedent to access a GCF for instance. While Rwanda established its first direct access to GCF for instance, Nigeria just established NDB as its first direct access entity to GCF.

To avoid the dangerous impact of climate change, global mean temperature increase must be reduced to 2^0C above pre-industrial levels. Mopping up domestic funds alone to address environmental challenges and promote sustainable development in Nigeria will not be adequate. Experts' estimated amount to achieve Nigeria's adaptation and resilience targets by 2030 is put at 120 billion USD through 2030 (Nationally Determined Contributions, 2021). A lot of finance needs to go into policy, planning, and mainstreaming adaptation policy into national development programs. Development of early warning systems, risk assessment and tracking, all require adequate funding which the Nigerian government cannot achieve due to its increased financing needs to reach development goals and climate targets.

Nigeria has, through its Nationally Determined Contributions (NDC), Long-Term Climate Strategies (LTS), and National Adaptation Plans (NAP) put forward ambitious targets to reduce GHG emissions and increase its resilience to climate change impacts. A recent analysis by the United Nations Development Programme showed that finance remains a fundamental barrier to the acceleration of climate action in developing countries including Nigeria (United Nations Development Programme, 2023). Financing sectoral opportunities such as bio-diversity, nature, agri-food, sanitation and water are investment opportunities.

High-income countries with a significant historical contribution to climate risks had committed to raising finance to fund climate action in lower-income countries. However, this target has not been realised and even more funding is required to advance the green transition and enhance resilience in developing countries. Nigeria as one of the most populous and economically significant country in Africa faces a perpetual shortfall in investment. Climate finance could play an important role towards closing this gap, driving positive environmental and social impact while unlocking new opportunities for attracting investment and innovation, improving resilience to climate-related risks that it faces.

Nigeria has not had the opportunity to access from the enormous available volume of the global climate fund. Between 2019 and 2020, it only received a fraction of this global funding totalling about $1.9 billion despite its status as one of the world's most vulnerable countries to the impacts of climate change (UKNiAF, 2024). Between 2021 and 2022, Nigerian climate finance grew by 32% to $2.5 billion representing just 8% of the estimated $29.7 billion estimated climate finance needs needed annually for mitigation and adaptation until 2030 (Landscape of Climate Finance in Ethiopia).

While advocating for climate-resilient and low-carbon development, creating enabling environment that provides support for this quest is an important step in accessing climate finance. This is notwithstanding the assurance of the institutional capacity that will implement already established policies. There is a high degree of insufficient technical expertise, human resources, knowledge and monitoring management systems that hinder effective planning, coordination, and reporting of climate-related expenditures at the

Ministries of Environment, Budget and Planning and the Debt Management Office. An institutional approach, based on capacity assessments, could provide insights at national and international levels, on the appropriate next steps for climate finance actions. Apart from capable institutions, Nigeria needs to develop the ability to manage funds and develop projects that respond to social needs indicative of clear effect and result-oriented.

4. Challenges of Accessing Climate Finance Fund

4.1 Complex Application Procedure

The biggest challenge in accessing climate finance is the stringent or complex application requirements by the climate finance providers. Climate finance providers often require highly detailed project proposals, feasibility studies, and evidence of long-term impact projects. Preparing these can be resource-intensive for Nigeria and other developing countries as they often lack the necessary capacity or technical expertise. But Rwanda has been able to overcome this challenge. It succeeded in simplifying its access to climate finance through the establishment of the Rwanda Green Fund (FORNEWA), a centralised mechanism that integrates and streamlines the process of mobilising and managing climate finance. The centralised structure consolidates resources from both international and domestic sources, thereby reducing the need for multiple layers of bureaucracy.

4.2 Limited Direct Access to Funds

Climate finance funds require intermediate bodies such as national implementing entities to access the fund. For now, the Development Bank of Nigeria (DBN) is accredited as a Direct Access Entity (DAE) for the GCF. The accreditation allows Nigeria the ability to directly access GCF resources for climate-related purposes without intermediaries (Ujah, 2024).

4.3 Insufficient Funding

The estimated global climate finance required annually is in the neighbourhood of $8-9 trillion by 2030 to keep global temperatures below 1.5^0C. Between 2021 and 2022 the global climate finance flow was $1.3 trillion leaving a huge gap. Insufficient funding is a major issue as the amount of climate finance that is currently available is not enough to meet the needs of developing countries who are more vulnerable and hit by climate change.

4.4 Limited Capacity

One of the key constraints faced by Nigeria and many developing countries in accessing climate finance relates to disjointed data availability and time lag in reporting conducted in a periodic manner (Global Centre on Adaptation). This is coupled with what Chennells referred in his research as 'insufficient absorptive capacity' i.e., inability of their institutions to properly execute projects and deliver programmes using the resources accessed (Channells, 2015).

Again, most developing countries lack the technical expertise or institutional capacity to develop projects that meet international standards. For instance, the GCF requires direct access modality which allows countries to directly access and manage climate finance. Countries interested in direct access to the GCF must first undergo an accreditation process, and a nationally designated authority or an eligible entity within the country will apply to become an Accredited Entity (AE) to the GCF. Once accredited, the AE then develops and submits project proposal that aligns with the GCF's funding priorities, objectives and eligibility criteria and probably address the nation's climate change priorities. Typical projects may include renewable energy initiatives, ecosystem restoration, climate-smart agriculture, climate resilient infrastructure, capacity-building programs, and infrastructure developments. Failure to develop bankable projects is at the core of denial to GCF and AF.

4.5 Corruption, Voice and Accountability

An empirical study conducted by Lubinga and Mazenda revealed that a perceived political instability significantly influenced climate finance inflows among countries that strongly increased their NDC targets, while perceived deterioration in corruption control negatively impacted the amount of climate finance received by the same group of countries (Lubinga and Mazenda, 2024). The study further showed that a poor perception of citizens' ability to express their voices according to dictates of the law and the extent to which citizens can participate in selecting their governance (voice and accountability) were linked to a decline in the amount of climate finance received among countries that increased their respective NDCs. Poor institutional governance relating to voice, accountability and corruption control are associated with reduced climate finance inflows in developing countries.

Perceived government effectiveness negatively affects climate finance inflows among developing countries.

A bad perception of government efficiency in delivering services compromises the chances of receiving climate finance. This could be attributed to bad confidence, which relies on decision-making and the capacity to make adequate and efficient decisions that further influence continued funding (Sheriffdeen, 2020). An enabling environment is essential and cannot be compromised in attracting climate fund. Building a strong accountability mechanism at all levels of government will be effective for Nigeria's government to access climate fund.

5. Policy Recommendations

Nigeria has made giant strides in accessing the global climate fund especially the GCF through the newly introduced DBN which empowers Nigeria to submit funding proposals directly for bankable projects. However, as at the time of writing this research, Nigeria has not received direct funding from the GCF. To improve access and mobilise sufficient fund, Nigeria government can leverage on Rwandan's best practices in accessing climate fund. Adopting a centralised climate finance system like Rwanda's Green Fund (FONERWA) could be transformative for Nigeria. This will improve access, transparency and efficiency in managing climate finance.

5.1 Development of Bankable Projects: Investment in climate resilience projects will encourage access to global climate finance. Gender related projects and actions targeted at reducing greenhouse gas emissions are more likely to receive GCF attention than others.

5.2 Strengthen Institutional Capacity: Investing in training experts within the fund is necessary to craft high quality proposals that meet the international standards to address the current challenges with bankable projects. Collaborating with international partners such as Rwanda to learn best practices for fund management and implementation is necessary.

5.3 Simplified Access: Establishment of centralised mechanisms that integrate and streamline the process of mobilising and managing climate finance will help to avoid complexities and bureaucracy often faced by developing nations in accessing global climate finance. FONERWA has established clear eligibility criteria and streamlined procedures for project evaluation and approval, which simplifies the procedure for applications. These measures enable Rwanda to effectively manage climate finance and avoid the challenges of navigating complex financial structures. Nigeria could consider adopting a similar centralised approach to improve its access to international climate funds.

5.4 Private Sector Engagement: An enhanced private sector engagement is crucial to building a resilient environment. Engaging the private sector to co-finance projects and leverage additional resources for climate initiatives, developing clear guidelines and eligibility criteria will ensure transparency and accountability that would build confidence among international donors and local stakeholders. Offering financial incentives such as tax holidays or grants will encourage private sector's investment in climate projects.

6. Lessons from Rwanda

Rwanda like Nigeria has been facing a long-term financial impact of the COVID-19 pandemic which left the country with limited financial resources allocated to vital climate mitigation and adaptation projects. Apart from the aftermath of COVID-19, Rwanda is considered highly vulnerable to climate change in both mitigation and adaptation cases. Having experienced multiple climate hazards including more intense rainfall, shifting seasonal temperatures, droughts and landslides, Rwanda has set ambitious climate and development goals to achieve a low-carbon emission, climate resilient economy.

The Government of Rwanda in 2012, established a Fund for the Environment and Climate Change referred generally as FONERWA, a cross-sectoral financing mechanism to achieve the development objectives of environmentally sustainable, climate resilient and green economic growth. The Fund was a ground-breaking initiative and the biggest in Africa. By leveraging on the institutional inclusivity across institutional learning and engagement at local level, Rwanda has successfully accessed some level of climate finance.

FONERWA serves as a vehicle through which green finance is channelled, programmed, disbursed and monitored. Nigeria should borrow a leaf from the successes of Rwanda to enhance and strengthen project development capacity especially now that it has established the DBN. Rwanda is one developing country that succeeded in establishing a dedicated climate fund which helped in the access to climate fund, with the ability to managing fund and proper development of projects.

It is an instrument to facilitate direct access to international environment and climate finance, as well as to streamline and rationalise external aid and domestic finance. Ministries, districts, charitable and private entities including businesses, civil society and research institutions have access to the Fund (Centre

for International Development and Training, 2014). The success of FONERWA lies with a successful integration of both management and technical board composed of governmental and non-governmental institutions as well as funders which allows the pooling of resources from different entities for climate finance. It serves as a primary means through which climate and environment finance in Rwanda is channelled, distributed and monitored.

The NDB role is equivalent to Rwandan's FONERWA. Ensuring that capacity exists to access the Fund both within the public and private sector is a top priority in its success. Potential beneficiaries, the private sector, especially the Micro, Small and Medium-sized Enterprises (MSMEs) that make up 96.7% of all businesses and contribute to over 45% of Nigeria's gross domestic product (GDP) can harness this opportunity to access loans to develop innovative and new business models, and low-carbon technologies that will drive Nigeria's economy towards its green goals. Training of manpower is also required to ensure that beneficiaries understand how climate finance works, how to scope eligible projects and how to structure successful proposals.

7. Conclusion

Climate finance is vital to addressing climate change due to the large-scale investments that are needed to transition to a low-carbon global economy, helping societies to build resilience and adapt to the impacts of climate change. Climate finance in Nigeria is small compared to the potential and financial needs of Nigerian communities. The huge debt status, debt servicing, institutional incapacity, inability to have direct access to global climate finance and wider investment issues militating against investment in climate solutions need critical attention. Nigeria needs to harness the international and national finance to give solution to the climate crisis in Nigeria. There is a need for scaling up climate finance through the development of domestic funds by leveraging on private-public partnership to support the inflow of global climate finance. Establishing a more simplified-centralised mechanism that integrates and streamlines the process of mobilising and managing climate finance are essential for building a more suitable and resilient future for the children yet unborn.

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NIU Journal of Climate Justice and Governance Copyright©2026
Nexus International University ISSN: *3007-1828;* 12(1): 17-26

Influence of Socio-Economic Characteristics of Oil Palm Farmers on Access to Climate Change Information in Delta State, Nigeria

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Abstract. This study examined the influence of socio-economic characteristics of oil palm farmers on access to climate change information in Delta State, Nigeria. Data were collected using cross-sectional survey data from 165 respondents selected through appropriate sampling procedures. The study was conducted with the objectives of describing the socio-economic characteristics of oil palm farmers and identifying their awareness, access to, and preference for various sources of climate change information. Descriptive statistics were used to analyze the data. The socio-economic profile of the respondents revealed that a substantial proportion of farmers were within the middle-aged category, with a mean age of 45.45 years, and majority (91.5%) were married. Females constituted 52.1% of the respondents, indicating strong female participation in oil palm farming. In terms of education, 47.3% had secondary school education, while only 10.3% had no formal education. The respondents had an average household size of 6.67 persons, mean farming experience of 14.40 years, and mean oil palm farming experience of 18.52 years. The average farm size was 5.56 hectares, and a majority were members of farmer associations. Findings on climate change information revealed that awareness levels were generally high, with extension agents, the internet, radio, and mobile phones ranking prominently in awareness and preference. However, actual access to formal institutional sources such as meteorological agencies and scientific journals remained low. Informal sources including fellow farmers, family members, friends, and neighbours played a dominant role in information dissemination. The study concluded that while oil palm farmers in Delta State demonstrate moderate awareness and diverse information access channels, reliance on informal networks persists due to limited institutional outreach. It is therefore recommended that extension services be strengthened, digital and mobile-based advisory platforms be expanded, and socio-economic factors such as education, gender, and association membership be strategically leveraged to improve equitable access to timely and reliable climate change information among oil palm farmers in Delta State.

Keywords: Oil palm, Climate change, Delta State, Access, Information

1. Introduction

Agriculture remains an important sector of Nigeria's economy, providing livelihoods for the ever-growing population. However, the sector is highly vulnerable to climate variability due to its dependence on rain-fed systems and the predominance of smallholder farmers with limited resources. Climate change has evolved rapidly, manifesting in erratic rainfall, flooding, prolonged droughts, and temperature fluctuations. These climatic shifts threaten agricultural productivity and rural livelihoods. Research has shown that the Nigerian agricultural sector is particularly vulnerable because it is dominated by poor, undernourished, uneducated farmers with low technological capacity and inadequate adaptive resources

Although farmers perceive climate change and attempt to adapt through local practices (Adepoju & Oyedepo, 2024), their ability to respond effectively depends largely on access to reliable climate information. Danso-Abbeam et al. (2021) observed that even farmers who adopt adaptation techniques remain vulnerable, suggesting that adaptation strategies must be informed by accurate and timely information. Climate change information such as seasonal forecasts, early warning systems, and agro-advisoriesenables farmers to make strategic decisions that minimize risks and optimize production.

However, access to climate information varies among farmers. Socio-economic characteristics such as age, education level, farm size, income, farming experience, membership in cooperatives, access to extension services, and ownership of communication devices significantly influence the ability to obtain and utilize climate information. Haider (2023) emphasized that understanding the determinants of farmers' adaptation decisions is crucial for designing effective policies. Socio-economic factors shape farmers' exposure to information channels, their comprehension of technical advisories, and their willingness to adopt recommended practices.

In oil palm-producing regions such as Delta State, socio-economic disparities may influence access to agro-climatic information. Oil palm (Elaeis guineensis) is a vital food and cash crop in Nigeria, historically central to trade and rural economies. Its major product, palm oil, is rich in carotene and serves both nutritional and industrial purposes. The crop remains economically significant across the tropics and plays a major role in income generation for rural households. Processing oil palm fresh fruit bunches involves several labor-intensive stages including threshing, picking, parboiling, digestion, extraction, and separation (Adeniyi et al., 2019).

Climate variability directly affects oil palm productivity. Excess rainfall may disrupt harvesting and processing activities, while insufficient rainfall can reduce fruit yield. Consequently, timely access to climate information is critical for oil palm farmers to adjust planting schedules, manage plantations, and plan processing operations effectively. Studies have demonstrated that appropriate use of agro-climatic information can increase crop yields by approximately 30% (Olutoye, 2019). Yet, access to such information depends heavily on socio-economic conditions.

Furthermore, language and communication methods significantly affect accessibility. Ladan and Addo (2024) noted that agricultural information delivered in local languages enhances understanding and encourages adoption. In rural communities of Delta State, farmers who lack exposure to formal extension services may depend on interpersonal communication networks for information. Gender dynamics may also play a role, as women farmers often face greater barriers in accessing extension services and climate advisories.

Therefore, analyzing the influence of socio-economic characteristics on access to climate change information among oil palm farmers in Delta State is essential. Such analysis will identify disparities and structural barriers that hinder equitable information distribution. By understanding which socio-economic factors significantly determine access, policymakers and extension agencies can design targeted interventions to improve information dissemination.

1.1 Research Objectives

- To describe the socio-economic characteristics of oil palm farmers in Delta State.
- To identify respondents' **access to** sources of climate change information.

1.2 Research Hypothesis

Ho: There is no significant relationship between socio economic characteristics of respondents and their access to information channels.

2. Research Methodology

2.1 Area and Scope of the Study

This study will be carried out in Delta State and Edo State, Nigeria. Delta State is an oil and agricultural producing state in Nigeria, situated in the region known as south-south geo-political zone with a population of 4,098,291, (males: 2,674396; female: 2,024,085). (National Population Census, NPC, 2006). The capital is situated in the city of Asaba. The state has a total land area of 16,842 square kilometers (6,503 m^2). The state is made up of three agro-ecological zones, Delta North, Delta Central, and Delta South Zone. Delta State comprises of 25 local government areas, share common boundaries with Edo State at the North, Ondo State towards the North West and bounded in the East by Anambra State. Delta State lies roughly between coordinates 5.00˚ and 6.30˚. The state has an average rainfall of about 2667 mm in the coaster area and 1095 mm in the North Area. The rainfall is heavier in July with a short break in August.

Some examples of crops grown in Delta State are cassava, cocoyam, yam, oil palm, plantain, potato, etc.

Edo State on the other hand is also located in the south-south geo-political zone of Nigeria with a total population of about 3.2 million people. Edo state lies within the geopolitical coordinates of latitude 05˚44 and 07˚34 North of the equator and longitude 05˚04 and 06˚43 East of the careen which meridian. The area is approximately 17,802kmsq. The topography of the state is generally low-lying rising gradually towards the North with the somorica hill at 600 metres being the highest point. The state is made up of three agro-ecological zones; these are Edo South, Edo Central and Edo North with a temperature ranging from 21-25˚c during cold weather to about 26-34˚c in hot weather of the region, Edo State is bounded in the North-East by Kogi and South East by Delta State, and in the West by Ondo State. The state is mainly an agrarian state with major cropping of cash such as timber, oil palm, cocoa, rubber, cocoyam, plantain, banana, livestock such as piggery, poultry and small ruminant are reared.

3.2 Population of the Study

The population of the study will be all the oil palm farmers in Delta and Edo State.

3.3 Sampling Techniques and Sampling Size

The study area consists of 43 local government areas with 6 geopolitical zones.

A multistage sampling procedure will be used for this study as follows:

First Stage: 2 local government areas will be randomly selected from each of the six agro-ecological sones

Second Stage: 2 communities will be purposively selected from each of the local governments due to the presence of oil palm farmers in these areas giving a total 24 communities.

Third Stage: 7 respondents will be selected randomly from each of the 24 communities. A total of 168 questionnaires will be distributed to the oil palm farmers, that will be selected randomly using a ballot system from each village/community initially selected in the state.

3.4 Instrument for Data Collection

Data of study will be collected primarily through the use of a well-structured questionnaire divided into different sections. Section A will be to solicit response on the socio-economic characteristics of the respondents e.g. age, marital status, level of education, income etc and other sections for other questions, secondly information sources like the internet, textbooks and journals will be used etc.

Section B will be soliciting responses on climate change information sources.

3.5 Measurement of variables

The variables will be classified as dependent and independent variables

Independent Variables

Socio-economic characteristics: this will be measures by asking respondents to indicate where necessary their actual age will be measured in years, sex, marital status as married, single, divorced etc. household size, farm size, production (small, medium, large), level of education, estimates of monthly and annual income etc.

Dependent Variables

Accessing sources of information through communication channels which will include internet, journals, researcher, newspaper, magazines, radio, oil palm research institute, other farmers, national hydrological and meteorological services, meetings, phone calls, office calls, seminars, posters, individuals farm visit and televisions.

Access to information will be measured in a three-point rating scale of high access scored three (3), access scored two (2), no access scored one (1). A mean score of 2.0 (3+2+1=6/3=2) this will be taken to mean that respondents have access to a particular information source in accessing climate change information.

3.6 Data Analysis

Objectives were analyzed using descriptive statistics like frequency counts, percentages, mean and standard deviation, while inferential statistics like logistic regression analysis was used to address the hypothesis stated.

Hypothesis of the Study

Hypothesis: There is no significant relationship between socio economic characteristics of respondents and their access to information channels. This will be achieved by t-values generated from the multiple regression analysis of the socioeconomic variables (X_1-X_{15}) and their access to information (Y) climate information sources of oil-palm channels scores will be used as the dependent variable

The regression model is given as

Xi-Xn = The independent variable

u= Error term

The mathematical expression of the mode; is explicitly specified as

$Yi= b_0 + b_1X_1 + b_2X_2\ b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6\ b_7X_7 + b_8X_8 + b_9X_9$ - - - - - - - 2

Where:

Y_1 = Information sources utilization (high =1, low =0)

X_1 = Age

X_2 = Sex

X_3 = Marital status

X_4 = Level of education

X_5 = Farming experience

X_6 = Household size

u= Error term

3. Results and Discussion

Table 1: Description of the socio-economic characteristics of oil palm farmers

Variables	Delta, n = 165 Freq	%
Age in years		
Less than 30	9	5.5
30 - 39p	39	23.6
40 – 49	71	43.0
50 - 59	21	12.7
60 and Above	25	15.2
Mean (Std. Dev)	45.45 (10.95)	
Sex		
Male	79	47.9
Female	86	52.1
Marital status		
Single	9	5.5
Married	151	91.5
Divorce	2	1.2
Widow	3	1.8
Level of education		
No formal education	17	10.3
Primary school	59	35.8
Secondary school	78	47.3
Tertiary education	11	6.7
Household size		
<5	58	35.2
5- 9 persons	83	50.3
10 persons and above	24	14.5
Mean (Std. Dev)	(2.59)	
Farming experience in years		
<10	29	17.6

Variables	Delta, n = 165 Freq	%
10 - 14 yrs	61	37.0
15 - 19 yrs	47	28.5
20 years and above	28	17.0
Mean (Std. Dev)	14.40(6.22)	
Farm size (ha)		
<5 ha	73	44.2
5- 9ha	81	49.1
10 ha and above	11	6.7
Mean (Std. Dev)	5.56 (2.59)	
Other crops		
Arable crops	83	50.3
Fruit	29	17.6
Vegetables	53	32.1
Estimate annual income from your oil palm		
<300,000	21	12.7
300,000 - 500,000	72	43.6
500,000 - 1,000,000	38	23.0
1,000,000 and Above	34	20.6
Mean (Std. Dev)	477,480.92 (182,038.26)	
Membership of associations**		
Oil palm farmers associations	101	61.2
Cooperative society	51	30.9
Weekly contribution	8	4.8
Monthly contribution	69	41.8
None of the above	14	8.5
Group leadership		
No form of leadership	30	18.2
Have led a group	29	17.6
Member	75	45.5
Other position	31	18.8
Contact with extension agents	62	37.6
Frequency of contact with extension agents		
Fortnightly	29	17.6
Monthly	12	7.3
Months interval	21	12.7
Never had contact	103	62.4

Source: *Field Survey, 2025.*

The Table above indicates that a majority of oil palm farming activities is highly prevalent among middle-aged and older adults in Delta State. The cultivation of oil palm is dominated by middle-aged people with good farming experience, particularly of perennial crops. According to Martey et al. (2013), with more farming experience, farmers are able to develop more productive strategies. Furthermore, farmers who have a higher capacity to adapt can better respond to the changes in climate, pests, and prices. The age distribution confirms the theoretical expectation on sex distribution in the sense that females have an edge over the males in Delta State as talk farming 52.1% cardigans as their VICE versa.

The educational qualifications reveal further that 47.9 per cent of the farmers had secondary education while only 10.3 One per cent. It indicates that farmers have strong human capital. Educated farmers are likely to better understand extension messages, which will help them adopt better farm practices (Asfaw and Admassie 2004). An average household typically accommodates 6.67 people. That's consistent with arrangements of extended family (World Bank, 2020). It indicates an abundant supply of labor but a greater dependence. On average, the farmers possess 14.40 years of farming experience. As indicated, this has a better level of knowledge about agricultural information and practice. Findings suggest that farmers with more years of experience are more likely to use improved technology and produce more than less experienced farmers. Farmers possess an average farm size of 5.56 hectares. It provides more opportunities for diversification of crops and economies of scale. In Delta State, 50.3% of farmers cultivate oil palm as an arable crop. Intercropping is very common. Diversified farmers are more sustainable and productive (Pretty et al 2011).

The average annual profit derived from oil palm is ₦477,481 while the majority of the respondents (50.6%) made above ₦500,000 yearly. The oil palm respondents enjoy a higher income as they may be having larger farm sizes or better management practices or the use of better seedlings. According to Olagunju (2008), being far from the road and processing centre affect the rate of profit to ascertain whether oil palm farmer's association membership affects their profit rate, 61.2% of the respondents revealed possessing association membership regarding oil palm and 41.8% of them indicated making monthly financial contributions to such associations. Bernard and Spielman (2009) contend that the organization of farmers lower transaction costs and enhance bargaining power. While 18.2% said they were not leading any farmer group. This means that most respondents hold a leadership position in organizations that can facilitate their collective association and representation. Further, 37.6 per cent of respondents said they have some contact with extension agents. Anderson and Feder (2007) showed that regular extension contact is positively associated with improved agricultural efficiency and uptake of best management practices. Even though the current interaction has a potential for meaningful knowledge transfer, extension engagement can certainly be improved.

Table 2: Access to information sources to climate change among farmers in Delta State

Climate Change Information	Radio Freq	Radio %	TV Freq	TV %	Newspaper Freq	Newspaper %
Crop forecasting	32	19.4	27	16.4	38	23.0
Oil palm information	67	40.6	42	25.5	48	29.1
Sunshine	51	30.9	21	12.7	40	24.2
Soil fertility	57	34.5	43	26.1	41	24.8
Pest/Disease management	73	44.2	58	35.2	37	22.4
Weather forecasting	30	18.2	33	20.0	35	21.2
Desert encroachment	19	11.5	51	30.9	22	13.3
Precipitation	40	24.2	42	25.5	43	26.1
Indigenous knowledge	35	21.2	43	26.1	38	23.0
Flooding	53	32.1	50	30.3	36	21.8
Temperature	45	27.3	28	17.0	53	32.1
Bush burning	32	19.4	26	15.8	18	10.9

Climate Change Information	Internet Freq	Internet %	Journals Freq	Journals %	Nigerian Meteorological Station Freq	Nigerian Meteorological Station %	Phone Calls Freq	Phone Calls %
Crop forecasting	18	10.9	10	6.1	6	3.6	60	36.4
Oil palm information	20	12.1	5	3.0	4	2.4	82	49.7
Sunshine	41	24.8	8	4.8	7	4.2	60	36.4
Soil fertility	28	17.0	5	3.0	8	4.8	51	30.9
Pest/Disease management	41	24.8	8	4.8	4	2.4	40	24.2

Weather forecasting	29	17.6	6	3.6	6	3.6	52	31.5
Desert encroachment	41	24.8	8	4.8	5	3.0	43	26.1
Precipitation	36	21.8	10	6.1	7	4.2	51	30.9
Indigenous knowledge	33	20.0	6	3.6	3	1.8	58	35.2
Flooding	19	11.5	18	10.9	6	3.6	40	24.2
Temperature	45	27.3	12	7.3	3	1.8	39	23.6
Bush burning	21	12.7	16	9.7	7	4.2	50	30.3

Oil palm farmers in Delta State access climate change and agricultural information through a multiplicity of channels, including phone calls, radio, television, newspapers, extension agents, social networks, and indigenous knowledge systems. However, the extent of utilisation varies significantly across information domains such as crop forecasting, pest and disease management, soil fertility, flooding, and oil palm production practices. The findings reveal a continued reliance on informal and interpersonal channels, alongside a marked underutilisation of scientific and institutional sources. Phone calls and radio emerge as the most dominant information channels. Phone calls are particularly preferred for crop forecasting (36.4%), oil palm information (49.7%), and sunshine data (36.4%), while radio is most frequently accessed for pest and disease management (44.2%), soil fertility (34.5%), and oil palm information (40.6%). These media are especially effective in rural settings with limited infrastructure and variable literacy levels, as they enable real-time, low-cost communication with geographically dispersed populations (Aker, 2011; Chapota et al., 2014). Television and newspapers play a moderate but relevant role, with television showing strong engagement for pest management (35.2%) and flooding (30.3%), and newspapers featuring prominently for temperature (32.1%) and precipitation (26.1%). However, the effectiveness of these traditional media is shaped by literacy, cost, and publication frequency, potentially limiting their reach among poorer or more remote farming communities (FAO, 2016; Below et al., 2012). Conversely, scientific and institutional sources remain severely underutilised. Journals peak at only 10.9% for flooding information, and the Nigeria Meteorological Station (NiMet) does not exceed 7.3% across any issue. This is concerning given the critical role of such institutions in providing accurate, forecast-driven, and science-based agricultural data. The minimal reach points to communication breakdowns, low awareness, and the absence of user-friendly dissemination practices. Anderson and Feder (2007) argue that effective extension systems must bridge this gap by translating scientific data into practical, accessible insights for farmers. Information demand is largely driven by immediate, practical farming concerns. Oil palm information is the most accessed topic (49.7% via phone calls; 40.6% via radio), followed by pest and disease management (44.2% via radio; 35.2% via television). In contrast, topics such as desert encroachment, weather forecasting, and bush burning show relatively low engagement, with desert encroachment accessed by only 11.5% via radio and 13.3% via newspapers. While these issues carry significant long-term agricultural implications, they appear less visible in local discourse and are perceived as gradual rather than immediate threats. This aligns with Pretty et al. (2011), who note that farmers are more responsive to short-term, visible threats than to abstract or slowly unfolding environmental processes Indigenous knowledge features prominently, with 35.2% of farmers citing it as a source for crop forecasting, precipitation, and soil fertility. This underscores the continued importance of traditional ecological knowledge, especially where formal sources are absent. Nyong et al. (2007) advocate for knowledge co-production—the integration of indigenous and scientific systems—as a strategy to enhance local adaptation capacity. Furthermore, fellow farmers and family members are the most frequently cited sources across nearly all categories, confirming the primacy of social networks in rural information dissemination (Nguyen et al., 2020; Bernard et al., 2008). Meetings and individual farm visits, while effective for personalised technical transfer, remain underutilised due to logistical and funding constraints (Anderson & Feder, 2007). Extension agents serve as only a moderate information source, cited for soil fertility (15.2%), flooding (16.4%), and temperature (18.8%). Although Delta State shows slightly higher engagement than some regions, usage rates remain below 20%, underscoring the continued need for revitalising extension systems hampered by low staffing, poor funding, and outdated tools (Aigbe et al., 2021). Strengthening both formal and informal channels, while integrating indigenous knowledge, is essential for improving climate information access and adaptive capacity among oil palm farmers.

Hypotheses Testing

Influence of Socio-Economic Characteristics and Access to Climate Change Information for Delta State

The regression model for Delta State is statistically significant ($F(8, 205) = 20.91$; $p < 0.001$), with an R^2 of 0.462 indicating that approximately 46% of the variation in farmers' access to climate change information is explained by the combined socio-economic variables, and an adjusted R^2 of 0.441 confirming the model's robustness. This is consistent with Musa et al. (2022) and Eze & Okonkwo (2023), who observed that structural and resource factors remain the main predictors of farmers' information access across southern Nigeria.

Educational attainment ($B = 0.041$, $p = 0.001$) significantly enhances farmers' capacity to seek, interpret, and apply climate-related data, with Adeyemi & Ifeoma (2023) and Nnadi et al. (2021) confirming that literacy directly influences comprehension of agricultural information and responsiveness to early-warning systems. Farm experience ($B = 0.026$, $p = 0.006$) also exerts a positive effect, as experienced farmers benefit from multiple cropping cycles and institutional contacts that strengthen seasonal knowledge, consistent with Tologbonse et al. (2018), who found that experience reinforces farmers' receptiveness to adaptive practices.

Access to credit ($B = 0.316$, $p < 0.001$) emerged as one of the most powerful predictors, enabling farmers to purchase communication devices, access mobile data, and attend extension seminars, with Onumadu and Osahon (2020) confirming that credit-accessible farmers are more involved in ICT-based climate information platforms. Extension contact frequency ($B = 0.355$, $p < 0.001$) is the strongest determinant overall, with Agwu et al. (2020) and Umeh & Ezeano (2022) emphasizing that extension visits remain the most effective channel for disseminating climate forecasts and adaptation technologies.

Market distance ($B = –0.024$, $p = 0.021$) negatively influences information access, as geographic isolation limits exposure to extension officers, social interactions, and ICT infrastructure, echoing Obayelu et al. (2019), who found that proximity to urban centres correlates with improved access to agricultural advisories. Household size ($B = –0.018$, $p = 0.046$) also shows a small but significant negative effect, with Ayoade et al. (2021) observing that household burden diverts attention from innovation uptake and reduces participation in cooperative and educational forums. Finally, membership in farmers' associations ($B = 0.288$, $p = 0.003$) positively and significantly affects information access, reaffirming the role of cooperative groups as information hubs that facilitate collective learning, group training, and linkage to extension and input suppliers, as emphasized by Onyebuchi & Musa (2021).

Table 4: Influence of socio-economic characteristics and access to climate change information among Farmers in Delta State

Independent Variable	Unstandardized Coeff. (B)	Std. Error	Beta	t-value	p-value	Significance
Age (years)	-0.008	0.006	-0.076	-1.333	0.184	Not significant
Educational level (years of schooling)	0.041	0.012	0.164	3.327	0.001	Highly significant
Farm experience (years)	0.026	0.009	0.152	2.785	0.006	Significant
Access to credit (1 = Yes, 0 = No)	0.316	0.071	0.224	4.451	0.000	Highly significant
Extension contact frequency (per month)	0.355	0.068	0.259	5.221	0.000	Highly significant
Market distance (km)	-0.024	0.01	-0.119	-2.333	0.021	Significant
Household size (no. of persons)	-0.018	0.009	-0.092	-2.008	0.046	Significant
Membership in farmers' association (1 = Yes, 0 = No)	0.288	0.095	0.168	3.029	0.003	Significant
Constant	1.421	0.327	–	4.347	0.000	–

$R^2 = 0.462$; Adjusted $R^2 = 0.441$; $F(8, 205) = 20.91$; $p < 0.001$

Source: *Field Survey, 2025.*

4. Conclusion and Recommendations

Climate change and its effects, though subject to continuous debate, have become an increasingly pressing global concern, as the magnitude of its impacts is already being felt by the general populace across various sectors of human endeavour.

Farmers in Delta State are already experiencing its effects firsthand and are finding ways to cope with the challenges it brings. However, the situation is expected to become increasingly difficult as time goes on. This makes it necessary for farmers to step up their own efforts while also receiving meaningful support from government agencies, non-governmental organizations, and private sector bodies. Together, these stakeholders must work to equip farmers with the knowledge, tools, and resources they need to better withstand and respond to the growing pressures of a changing climate.

Based on the findings of this study, it is recommended that agricultural inputs such as improved oil palm seedlings, fertilizers, pest control chemicals, irrigation facilities, and climate-resilient technologies be made readily available and affordable to farmers before the onset of the planting season through targeted subsidy schemes and cooperative-based distribution systems. Timely and simplified weather and climate forecasting information should be disseminated through trusted and widely accessed channels such as mobile phones, radio, farmer associations, and community meetings prior to critical farm decision periods. Extension services in Delta State should be strengthened through increased deployment of trained personnel, regular farm visits, demonstration plots, and farmer field schools, while integrating indigenous knowledge with scientific climate information to improve relevance and trust. Government and development partners should encourage and support farmers' participation in training programmes, cooperative activities, and climate adaptation workshops, particularly focusing on women and youth who constitute a significant portion of the farming population. Furthermore, affordable and context-specific climate adaptation technologies should be developed, localized, and promoted to ensure accessibility for resource-poor farmers. These combined measures will significantly enhance the resilience, productivity, and long-term sustainability of oil palm farming systems in Delta State.

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Nexus International University ISSN: *3007-1828;* 12(1): 27-39

Urban Gentrification and Housing Affordability: Evidence from Iwofe Community, Port Harcourt, Nigeria

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Abstract. This study examines the impact of gentrification on housing affordability in Iwofe Community, Port Harcourt, Nigeria, addressing a critical gap in African and Nigerian gentrification research. Using a descriptive survey design with systematic random sampling, data were collected from 254 respondents who occupied housing units before 2020, enabling before-and-after comparisons of rental costs and housing affordability. Multivariate regression analysis identified factors driving rent escalation between the pre-gentrification (pre-2020) and post-gentrification (post-2020) periods. Results reveal severe deterioration in housing affordability. Weighted average rents increased 220% (from ₦373,228 to ₦1,193,465 annually), with housing-type-specific increases ranging from 100% for one-bedroom apartments to 268% for two-bedroom units. Critically, households experiencing severe affordability burden (spending ≥50% of income on rent) increased from 11.8% to 48.1%, far exceeding the 30% international threshold. Regression analysis demonstrates that gentrification-specific factors, particularly influx of higher-income residents (β = 0.318), urban redevelopment projects (β = 0.309), and infrastructure development (β = 0.304) collectively exert substantially greater influence ($\Sigma\beta$ = 0.931) on rent escalation than general inflation (β = 0.281). This establishes that Iwofe's affordability crisis reflects locality-specific gentrification dynamics rather than macroeconomic factors. The study provides robust empirical evidence that gentrification constitutes the primary mechanism undermining housing affordability for low- and middle-income residents in this Nigerian petroleum-producing city. These findings underscore the urgent need for gentrification-control policies, affordable housing programs, and community protection mechanisms in rapidly urbanizing African cities.

Keywords: Gentrification, Housing Affordability, Urban Development, Nigeria.

1. Introduction

Gentrification, broadly defined as the transformation of previously low-income or underdeveloped urban neighborhoods into more attractive areas through reinvestment, redevelopment, and demographic change, has become a significant process shaping contemporary cities (Oliveira, 2025). While the phenomenon has been widely studied in Western urban contexts, its manifestation in cities of the Global South presents distinctive characteristics and consequences that require context-specific investigation. In many developing cities, gentrification is associated with rising property values, increasing rental prices, and changing neighborhood demographics as higher-income residents and investors move into previously affordable communities. These changes often place pressure on existing residents by increasing the cost of housing and living, thereby affecting the affordability of accommodation for low- and middle-income households (Oliveira, 2025).

Across Sub-Saharan Africa, rapid urbanization and expanding urban economies have intensified competition for urban land and housing. As cities grow and attract investment, inner-city and strategically located neighborhoods often experience redevelopment and rising property values. These changes frequently translate into higher rents and housing prices, gradually reducing the ability of existing residents to maintain access to affordable housing. Although gentrification can contribute to physical improvements in urban environments, its economic consequences often include reduced housing affordability and increased financial pressure on long-term residents.

In Southern Nigeria, urban transformation has accelerated in recent decades as a result of economic growth, population increase, and expanding investment in real estate and infrastructure. Port Harcourt, the major economic hub of the oil-producing Niger Delta region, illustrates these dynamics. As the center of Nigeria's petroleum industry, the city has attracted significant public and private investment, leading to infrastructure upgrades, commercial expansion, and increased real estate development in several neighborhoods (Nwafor et al., 2018). While these developments contribute to urban modernization, they also create conditions in which property values and housing costs increase, particularly in areas that become attractive for residential and commercial investment.

The Iwofe Community, located within the urban area of Port Harcourt, has recently experienced noticeable physical and socio-economic changes. The community, historically characterized by relatively affordable housing and a concentration of low-income residents, has begun to witness new building developments, property upgrades, and increasing demand for residential space. These changes have contributed to rising land values and rental costs within the area. As a result, concerns have emerged regarding the extent to which ongoing urban transformation in Iwofe is influencing housing affordability for existing residents.

The relationship between gentrification and housing affordability is typically expressed through the capitalization of rising land and property values into housing costs. As neighborhoods become more attractive to investors and higher-income residents, demand for housing increases and property owners often adjust rents and prices upward to reflect the changing market conditions (Song & Chapple, 2024). This process gradually reduces the availability of affordable housing options within the affected neighborhoods and may compel lower-income households to seek accommodation in less desirable or more distant locations. Consequently, the affordability of housing becomes a critical issue in gentrifying urban areas.

Despite growing attention to housing affordability challenges in African cities, empirical studies examining how gentrification specifically influences housing affordability in Nigerian urban environments remain limited. Existing studies have largely focused on general housing shortages or rising urban housing costs, with relatively little attention given to the localized processes through which neighborhood transformation affects the affordability of housing for residents. This gap in knowledge is particularly important in rapidly transforming cities such as Port Harcourt, where urban development pressures continue to reshape residential neighborhoods.

The Iwofe Community therefore provides an important case for examining how gentrification processes influence housing affordability within a Nigerian urban context. As a neighborhood undergoing visible development and increasing investment interest, Iwofe reflects the broader tensions between urban redevelopment and the continued availability of affordable housing for existing residents. Understanding how these changes affect housing costs and accessibility within the community is essential for informing urban planning and housing policy aimed at promoting inclusive and sustainable urban development.

Against this background, this study examines the impact of gentrification on housing affordability in the Iwofe Community, Port Harcourt. The study seeks to provide empirical evidence on how ongoing urban transformation influences housing costs and the ability of residents to access and maintain affordable accommodation within the community.

2. Literature Review

2.1 Gentrification and Housing Affordability

Gentrification, commonly described as the transformation of working-class urban neighborhoods through reinvestment, redevelopment, and demographic change, has become a major process reshaping cities across both the Global North and the Global South (Oliveira, 2025). Originally conceptualized in 1970s urban scholarship to explain neighborhood succession in Western cities, the concept has since evolved to encompass a broader set of economic, social, and political processes. Contemporary scholarship recognizes gentrification as a multifaceted phenomenon involving the reinvestment of capital in previously undervalued urban spaces, the inflow of higher-income residents, and the escalation of property values (Gourzis & Alexandri, 2026). Central to the theoretical explanation of this process is the rent gap theory, which posits that gentrification occurs when a disparity arises between the existing capitalized ground rent of land under its current use and the potential ground rent that could be realized under more profitable uses (López-Morales, 2023). This disparity creates strong incentives for investors and developers to redevelop urban neighborhoods in order to capture the potential value difference.

Although gentrification is often associated with physical improvements in urban environments, its socio-economic consequences are frequently uneven. Urban redevelopment and increased investment often privilege higher-income groups while simultaneously creating pressures on existing low-income residents (Bosma, 2023). One of the most significant outcomes of gentrification is its effect on housing affordability. As neighborhoods attract investment and more affluent residents, demand for housing increases, leading to substantial increases in property values and rental prices. These rising housing costs gradually reduce the

affordability of accommodation for existing residents, particularly low-income households that may struggle to keep pace with increasing rents and living expenses (Song & Chapple, 2024). Empirical studies have shown that neighborhoods undergoing gentrification often experience housing price increases that significantly exceed those of non-gentrifying areas, thereby altering the financial accessibility of housing within these communities (Delmelle, 2021).

The affordability implications of gentrification are particularly pronounced for lower-income households. In many cases, households affected by rising housing costs are compelled to allocate a much larger share of their income to housing expenditure. Studies indicate that displaced residents in gentrifying neighborhoods may spend between 40 percent and 60 percent of their income on housing, far exceeding the commonly accepted affordability threshold of 30 percent of household income (Oyesomo et al., 2023). Beyond the direct escalation of housing costs, gentrification also increases competition for available housing units within urban areas. As housing prices rise in redeveloping neighborhoods, displaced or financially pressured residents seek accommodation in nearby areas, thereby extending affordability pressures to surrounding communities and peripheral locations (Etienne, 2025). In addition, investments in infrastructure and urban amenities, although beneficial to neighborhood development, often become capitalized into property values and rental prices, further reducing housing affordability for lower-income residents (Oliveira, 2025).

2.2 Empirical Studies on Gentrification and Housing Affordability

Empirical research on gentrification and housing affordability spans developed countries, emerging markets, and African contexts, yet significant gaps persist particularly regarding Nigerian secondary cities. In Western contexts, Song and Chapple (2024) investigated whether gentrification restricts housing markets for low-income households in New York and San Francisco using longitudinal dataset analysis from 2013-2019, finding low-income residents significantly more likely to leave gentrifying neighborhoods and less likely to enter them, though the study provided limited exploration of neighborhood characteristics beyond gentrification status influencing mobility (Song & Chapple, 2024). Paccoud (2016) examined buy-to-let gentrification in the United Kingdom through small-area tenure data comparison from 2001-2011, documenting how private rental market investment emerged as a prominent gentrification trajectory creating long-term displacement while failing to sufficiently analyze how rental market gentrification differs from ownership-based mechanisms. Martin, Shipman, and Ting (2024) employed qualitative case study combined with demographic analysis of out-migration from high-growth U.S. cities propelled by gentrification, revealing middle-class displacement into lower-cost regions though remaining inattentive to how receiving city communities experience gentrification pressures. Garmany and Richmond (2019) proposed the concept of "hygienisation" through conceptual analysis drawing on colonialism and state violence to distinguish Brazilian gentrification from Euro-American models, yet provided limited empirical documentation across cities and insufficient comparative analysis with African contexts.

African research on gentrification and housing affordability reveals substantial displacement and affordability crises though with significant evidential limitations. Maseko (2025) employed ethnographic research with 50 resident interviews examining Durban's Point Precinct state-led gentrification, finding 92% of participants reported housing becoming increasingly unaffordable and discovering gentrification creates compound displacement effects, though the study lacked longitudinal analysis to track displacement trajectories and insufficient examination of community resistance strategies. Boateng and Klopp (2024) challenged ahistorical housing crisis theorizations through critical postcolonial institutional analysis of Ghana, demonstrating persisting housing exclusion results from regressive investment patterns and elite institutional biases rather than demographic factors alone, yet provided limited empirical data quantifying affordability outcomes. Ngema, Bokhari, and Mbanga (2025) assessed social housing's urban regeneration impact through qualitative policy analysis and case studies across South African cities, finding social housing significantly expanded regulated units and alleviated low-income household financial burdens, though providing insufficient analysis of how social housing prevents gentrification displacement or achieves long-term affordability. Raj et al., (2025) evaluated Public-Private Partnership approaches for affordable housing in Dhaka through mixed methods combining qualitative interviews with policy review, documenting PPP potential while highlighting weak coordination and inflexible contracts limiting affordability for low-income groups, though providing limited long-term affordability outcome evidence. Etienne (2025) examined urban out-migration drivers in Sub-Saharan African cities using fixed effects quantitative analysis, finding inequality, rapid urbanization, and rising living costs drive significant out-migration from major cities confronting housing shortages, yet provided limited qualitative analysis of individual household decision-making and insufficient attention to gentrification-specific impacts.

Housing affordability studies in Ethiopian cities document severe unaffordability challenging government interventions. Teklemariam (2022) surveyed spatial equity implications of Ethiopia's Integrated Housing Development Program in Addis Ababa, discovering peri-urban residents perceive lower equity levels compared to inner-city residents while

location statistically significantly correlates with satisfaction, yet lacked analysis of gentrification pressures and insufficient examination of how displacement affects original community residents. Elias (2025) employed descriptive statistical analysis measuring housing affordability across Addis Ababa sub-cities using median multiple approach, finding housing extremely unaffordable for middle and low-income households with significant price variability, though providing limited trend analysis and insufficient examination of how infrastructure investment drives prices. Tareke and Baraki (2024) developed combined housing and transportation affordability index with GIS analysis across Addis Ababa location types, discovering outer-city residents face higher financial burdens despite lower housing costs due to transportation expenses, yet provided limited analysis of gentrification location-premium impacts. Uwayezu and de Vries (2020) assessed affordable housing accessibility in Kigali through price-to-income ratio analysis and household surveys, determining developed units remain severely unaffordable for target beneficiaries due to high development costs while formal housing serves only upper-income groups, though lacked analysis of gentrification dynamics in upgraded informal settlements. Regassa and Regassa (2015) examined condominium housing affordability in Hawassa City, Ethiopia through empirical assessment, finding government housing remains unaffordable for majority residents reflecting high development costs and limited household incomes, though providing limited longitudinal analysis of gentrification-specific mechanisms. Madell (2024) reviewed inclusionary housing policy and practice in South African cities through policy mechanism analysis, finding inclusionary housing can contribute to spatial transformation but requires integration with broader frameworks, yet provided limited empirical evidence on long-term affordability outcomes.

Nigerian housing affordability research demonstrates acute challenges though with minimal explicit gentrification focus. Oyesomo, Odunnaike, and Akinbola (2023) assessed Lagos State government social housing affordability through house price-to-income ratio analysis, determining units priced at N20-25 million remain unaffordable for low-medium income earners earning below N200,000 monthly, with government schemes inadvertently serving only upper-middle-income groups, though providing limited examination of neighborhood gentrification dynamics and insufficient analysis of how government schemes affect informal housing markets. Nwafor et. al. (2018) synthesized socioeconomic affordability determinants across Lagos, Abuja, Port Harcourt, and Kano through evidence synthesis examining employment, land tenure, construction materials, and mortgage infrastructure, establishing employment status as primary affordability determinant while land tenure insecurity constrains ownership, yet provided limited quantitative affordability trend analysis and insufficient examination of gentrification-specific dynamics. Iwuagwu (2025) investigated urban poverty-housing affordability-health links through questionnaire administration to 700 households across 10 Abia State slum neighborhoods, discovering slum neighborhoods impede health quality while poor housing affordability creates health risks, though lacking analysis of gentrification pressures and insufficient examination of displacement mechanisms. Port Harcourt's housing affordability remains dramatically understudied despite distinctive petroleum industry-driven dynamics creating speculative real estate investment and extreme price volatility (Elile & Raju, 2021). The city's informal land tenure system implementation remains weak, characterized by corruption and discretionary allocation enabling speculative hoarding and predatory transactions (Babalola & Hull, 2019), while low-income residents depend on informal housing markets involving tenure insecurity and inadequate quality (Yakubu et al., 2024), reflecting broader market-led provision patterns leaving low-income residents inadequately served (Uduokhai et al., 2023).

Cross-contextual policy research reveals implementation gaps despite theoretical frameworks. Bhanye et. al. (2024) conducted rapid literature review of sustainable innovative affordable housing strategies in African cities using thematic analysis, identifying multiple strategy approaches enhancing spatial justice yet requiring policy support and community engagement, though providing limited empirical evidence on gentrification prevention and insufficient analysis of strategy interactions with formal-informal housing market dynamics. Mhlongo, Gumbo, and Musonda (2022) reviewed low-income housing delivery in South Africa through case study analysis, arguing governance represents missing link in housing policy while housing processes largely exclude participation principles causing community resistance, yet provided limited empirical evidence on how governance improvements affect affordability outcomes. Enwin and Ikiriko (2023) examined affordable housing-urban sprawl nexus through literature review methodology, finding rising urban costs drive low-income populations to peripheries intensifying displacement and inequality, though providing limited empirical gentrification-sprawl relationship analysis. Chaudhary (2024) explored public policy's role in addressing housing affordability through literature review examining policy frameworks, finding public policy can enhance affordability but requires careful calibration with market forces, yet providing limited empirical evidence on specific policy effectiveness. Amin (2025) investigated socioeconomic factors influencing rental housing affordability in Dhaka through multiple regression analysis, identifying various determinants influencing affordability while younger and low-income residents face greater challenges, though lacking gentrification impact analysis. Wang, Fang, and Li (2025) explored daily activity space differences between income groups in suburban affordable housing communities in Nanjing

through personal-perspective methodology, discovering significant differences in activity spaces across income dimensions reflecting location-based inequality, yet providing limited gentrification pressure analysis. Ezani et. al. (2025) conducted bibliometric review mapping sustainability-affordability intersection using VOSviewer analysis of 973 publications, identifying five major research clusters and strong publication growth post-2019, yet demonstrating limited focus on gentrification-affordability connections and insufficient attention to informal housing.

Critical research gaps pervade the literature. Most fundamentally, gentrification-affordability nexus remains severely understudied in African and Nigerian contexts, with Nigerian housing literature focusing on general affordability challenges without explicitly examining gentrification as a driver or attending to how infrastructure investment affects accessibility (Nwafor et al., 2018). Limited research directly examines displacement mechanisms and resident experiences in gentrifying African neighborhoods, with few studies employing mixed-methods approaches combining quantitative affordability metrics with qualitative community perspectives (Maseko, 2025). Tenure transformation and informal housing dynamics during gentrification remain inadequately examined, as minimal research explores how gentrification interacts with complex tenure systems and customary land rights to create displacement pressures (Yakubu et al., 2024). Very few studies specifically examine gentrification-affordability dynamics in petroleum-dependent or resource-extractive urban economies like Port Harcourt, whose distinctive political economy shaped by petroleum wealth and volatile real estate speculation differs fundamentally from other African cities (Elile & Raju, 2021). Community responses and resistance to gentrification-driven affordability challenges remain underexamined in African and Nigerian contexts, with limited documentation of how residents organize against displacement or demand housing rights. Longitudinal research on gentrification's long-term affordability impacts is sparse, with most studies employing cross-sectional designs limiting capacity to track household trajectories. Finally, empirical evidence on gentrification-prevention policy effectiveness in African and Nigerian contexts remains underdeveloped despite policy recommendations appearing throughout literature. This study of gentrification's impact on housing affordability in Port Harcourt's Iwofe Community directly addresses these critical gaps by documenting resident experiences, housing cost dynamics, tenure transformations, and community responses in a gentrifying Nigerian petroleum-producing city neighborhood.

3. Research Mthodology

Iwofe is a rapidly urbanizing residential community located in Port Harcourt, Rivers State, Nigeria. The area has experienced significant physical and socioeconomic transformation in recent years due to its strategic location along major urban corridors and its proximity to commercial centers and educational institutions within the city. These advantages have attracted new residents, property developers, and real estate investors to the community.

In recent years, Iwofe has shown several features commonly associated with urban gentrification. Older residential buildings are increasingly being renovated or replaced with more modern housing developments, while improved infrastructure and expanding commercial activities have enhanced the attractiveness of the area. The influx of higher-income residents and private investment has contributed to a rising demand for housing within the community.

One of the most visible outcomes of these changes is the steady increase in rental values. Rental prices for residential apartments in Iwofe have risen considerably over the past few years, with one-bedroom and two-bedroom apartments experiencing significant price increases. This upward trend in housing costs reflects the growing demand for accommodation in the area and the transformation of the neighborhood into a more desirable urban residential location.

This study adopted a descriptive survey design to examine the impact of gentrification on housing affordability in Iwofe Community, Port Harcourt, Rivers State, Nigeria. Preliminary field investigations indicated that the community contains approximately 2,479 housing units, which constituted the study population. A systematic random sampling technique was employed in selecting the sample, with one out of every five housing units chosen for inclusion in the study. This procedure yielded a sample of 496 housing units. Since the study focused on the affordability implications of gentrification for tenants, emphasis was placed on rented residential properties. Where an owner-occupied property was encountered during the sampling process, the next available rented property was selected in order to maintain the focus on tenant-occupied housing. Within each selected housing unit, one respondent, preferably the household head, was surveyed because such individuals are typically most knowledgeable about household income and housing expenditure. Data were collected through a structured questionnaire designed to obtain information on respondents' socio-economic characteristics, year of entry into the apartment, rent paid before 2020 (identified as the period prior to the emergence of observable gentrification features in the community), rent paid after 2020, income range before 2020, income range after 2020, the proportion of rent change attributed by respondents to gentrification-related developments, and the general impact of gentrification on housing affordability. Although 496 questionnaires were administered, only 254 respondents indicated that they had been occupying their housing units prior to 2020, making it possible to obtain comparable information on housing conditions before and after the

period in which gentrification features became evident. Consequently, data from these 254 respondents were used for the analysis in order to facilitate a before-and-after assessment of changes in rent levels, income conditions, and housing affordability within the community. Data collected were analyzed using inferential and descriptive statistical techniques.

4. Results

This section presents the empirical findings of the study. The results are organized to provide a comprehensive understanding of how gentrification has reshaped the local housing market, beginning with the socio-economic characteristics of respondents, followed by residential tenure patterns, housing cost escalation, rent-to-income ratios, perceived drivers of rent increases, and multivariate analysis of the determinants of rent growth. By integrating descriptive statistics, cross-tabulations, perceptual measures, and regression analysis, the results highlight the relative importance of gentrification-specific processes, including demographic change, urban redevelopment, and infrastructure investment, compared with general inflation, thereby establishing the central role of locality-specific mechanisms in driving housing cost increases.

4.1 Socio-Economic Profile of Respondents

The respondent sample (n = 254) comprised primarily economically active individuals engaged in diverse occupational categories, reflecting the working-class composition typical of urban Port Harcourt neighborhoods. As shown in Table 1, the majority of respondents (66.2%) were between 31 and 50 years old, positioning them as primary household decision-makers responsible for housing arrangements. The occupational distribution revealed a high prevalence of trading and business activities (36.2%), supplemented by private sector employment (23.6%), public service positions (21.3%), and informal artisan work (18.9%). This occupational heterogeneity, combined with the prominence of informal and trading sector employment, indicates moderate- and unstable-income streams for most households. The vulnerability of these income patterns to economic shocks is particularly significant given that households consisting of 3–5 persons represented 57.5% of the sample, meaning that rent increases directly impact family welfare and livelihood security across a substantial portion of the community (Anguelovski et al., 2021).

Table 1: Socio-Economic Characteristics of Respondents (n = 254)

Variable	Category	Frequency	Percentage (%)
Age	20–30 years	44	17.3
	31–40 years	98	38.6
	41–50 years	70	27.6
	Above 50 years	42	16.5
Occupation	Trading/Business	92	36.2
	Public/Civil Service	54	21.3
	Private Sector	60	23.6
	Artisan/Informal Work	48	18.9
Household Size	1–2 persons	36	14.2
	3–5 persons	146	57.5
	Above 5 persons	72	28.3

4.2 Residential Tenure and Timeline of Gentrification Emergence

Respondents' year of entry into their current apartments provides important temporal context for understanding gentrification processes in Iwofe (Table 2). The distribution shows that 33.9% of respondents entered their apartments between 2018–2019, representing a concentration of recent arrivals during the period when gentrification pressures accelerated in the community. An additional 29.1% entered between 2015–2017, indicating that approximately 63% of the sample had occupied their current residences for less than five years at the time of the study. This pattern suggests active residential churn and suggests significant displacement of longer-term residents. The longitudinal implications of this distribution are notable: only 13.4% of respondents had occupied their apartments before 2010, indicating substantial population turnover and community demographic shifts consistent with gentrification-driven displacement patterns (Obaitor et al., 2024).

Table 2: Year of Entry into Apartment (n = 254)

Year of Entry	Frequency	Percentage (%)
Before 2010	34	13.4
2010–2014	60	23.6
2015–2017	74	29.1
2018–2019	86	33.9
Total	254	100

4.3 Housing Cost Escalation: Pre- and Post-Gentrification Comparison

The rents indicated before and after 2020 were computed into ranges and the resultant frequencies in each range categories are as presented in tables 3 and 4 below. A central finding of this study is the dramatic escalation of housing costs across all housing unit categories following the emergence of gentrification in Iwofe. Cross-tabulation analysis reveals stark contrasts in the distribution of rental values before and after gentrification, demonstrating a systematic upward price shift across the housing market.

Table 3: Housing Unit Type and Annual Rent Before Gentrification (Pre-2020)

Housing Unit Type	Below ₦200,000	₦200,000–₦300,000	₦301,000–₦400,000	₦401,000–₦500,000	Above ₦500,000	Total
Self-contain / 1-Bedroom	30	42	14	6	0	92
2-Bedroom Apartment	2	28	42	24	8	104
3-Bedroom Apartment	0	4	10	24	20	58
Total	32	74	66	54	28	254

Estimated Average Rent: ₦373,228

Prior to 2020, housing costs in Iwofe exhibited the typical structure of a non-gentrifying neighborhood. Self-contained and one-bedroom apartments were predominantly concentrated in the lower price categories, with 78.3% (n = 72) costing ₦300,000 or below, annually. Two-bedroom apartments showed wider price dispersion, with concentrations in the ₦301,000–₦500,000 range, representing 63.5% of this housing category (n = 66). Three-bedroom apartments, as larger units, commanded higher prices, with 70.7% (n = 41) priced above ₦400,000 annually. The overall rental structure reflected stratified housing markets typical of developing-country urban areas, where housing costs correlated proportionally with unit size and amenity provision (Nwafor et al., 2018). The estimated average pre-gentrification rent of ₦373,228 per annum aligns with regional housing market patterns and provides a baseline for assessing gentrification-induced price changes.

Table 4: Housing Unit Type and Annual Rent After Gentrification (Post-2020)

Housing Unit Type	Below ₦500,000	₦500,000–₦999,999	₦1,000,000–₦1,499,999	₦1,500,000–₦1,999,999	₦2,000,000 and Above	Total
Self-contain / 1-Bedroom	16	54	18	4	0	92
2-Bedroom Apartment	2	6	40	38	18	104
3-Bedroom Apartment	0	2	16	18	22	58
Total	18	62	74	60	40	254

Estimated Average Rent: ₦1,193,465

The post-gentrification rental landscape exhibits a fundamentally altered market structure characterized by systematic upward displacement of all housing categories. One-bedroom apartments show a dramatic leftward shift away from lower price brackets, with only 17.4% (n = 16) remaining below ₦500,000, compared to 78.3% below ₦300,000 in the pre-gentrification period. The modal category for one-bedroom apartments shifted to the ₦500,000–₦999,999 range (58.7%, n = 54), representing more than a doubling of typical rental costs. For two-bedroom apartments, the transformation is even more pronounced: none remained in the lowest price bracket, while the modal category shifted from ₦301,000–₦400,000 to ₦1,000,000–₦1,499,999 (38.5%, n = 40), representing nearly a tripling of typical rents. Three-bedroom apartments show the most dramatic restructuring, with no units remaining below ₦500,000 and the distribution concentrated in the ₦1,500,000 and above categories (69.0%, n = 40). These shifts provide compelling empirical evidence of gentrification-driven market restructuring (Aguilar-Velázquez et al., 2024).

Table 5: Percentage Change in Rent Before and After Gentrification by Housing Type (n = 254)

Housing Unit Type	Average Rent Before Gentrification (₦)	Average Rent After Gentrification (₦)	Absolute Increase (₦)	Percentage Increase (%)
Self-contain / 1-Bedroom	210,000	420,000	210,000	100%
2-Bedroom Apartment	380,000	1,400,000	1,020,000	268%
3-Bedroom Apartment	620,000	2,050,000	1,430,000	231%
Weighted Average	373,228	1,193,465	820,237	220%

The magnitude of rent escalation across housing categories demonstrates the pervasive impact of gentrification on Iwofe's housing market. Self-contained and one-bedroom apartments experienced a 100% increase, rising from an average of ₦210,000 to ₦420,000 annually. This doubling of rents for the smallest housing units represents a substantial affordability burden for lower-income households. Two-bedroom apartments exhibited even more pronounced

escalation, with a 268% increase from ₦380,000 to ₦1,400,000 annually, nearly a quadrupling of rental costs. Three-bedroom apartments, while experiencing a slightly lower percentage increase of 231%, still faced an absolute rent increase of ₦1,430,000, pushing average rents beyond ₦2,000,000 annually. Across all housing categories, the overall average rent increased by approximately 220%, from ₦373,228 before gentrification to ₦1,193,465 after gentrification. This magnitude of average rents increase occurs within a compressed timeframe (approximately 2015–2020), indicating rapid and intensive gentrification processes (Maseko, 2025). Notably, these rent increases substantially exceed typical inflation rates in Nigeria, suggesting that gentrification-specific factors rather than general macroeconomic inflation drive these escalations (Aguilar-Velázquez et al., 2024).

4.4 Housing Affordability Deterioration: Rent-to-Income Ratios

The deterioration of housing affordability in Iwofe is starkly revealed through analysis of rent-to-income ratios before and after gentrification, demonstrating that housing now consumes unsustainable proportions of household income.

Table 6: Rent-to-Income Ratio Before Gentrification

Rent as % of Income	Frequency	Percentage (%)
Below 25%	36	14.2
25–30%	68	26.8
31–35%	72	28.3
36–40%	48	18.9
Above 40%	30	11.8
Total	254	100

Prior to gentrification, the rent-to-income distribution reflected relative affordability within Iwofe's housing market. The majority of households (55.1%, n = 140) spent between 25% and 35% of their income on rent, approximating or slightly exceeding the internationally accepted housing affordability threshold of 30%. Only 11.8% of households (n = 30) exceeded the 40% threshold, indicating that most residents-maintained housing costs at or near acceptable affordability levels. This pre-gentrification distribution aligns with housing affordability patterns in other Nigerian urban centers prior to intensive gentrification pressures, reflecting relatively balanced housing markets where wage earners could access adequate shelter without extreme financial sacrifice (Ezennia & Hoşkara, 2019).

Table 7: Rent-to-Income Ratio After Gentrification

Rent as % of Income	Frequency	Percentage (%)
Below 30%	12	4.7
30–39%	42	16.5
40–49%	78	30.7
50–59%	68	26.8
60% and Above	54	21.3
Total	254	100

The post-gentrification rent-to-income distribution reveals a dramatic deterioration in housing affordability. The proportion of households spending below 30% of income on rent collapsed to 4.7% (n = 12), representing a 66% reduction from the pre-gentrification baseline. Conversely, the proportion spending 40% or more of income on housing ballooned to 78.8% (n = 200), representing a 6.7-fold increase from the pre-gentrification level of 11.8%. Most significantly, 48.1% of households (n = 122) now spend 50% or more of their income on rent, far exceeding the recommended affordability threshold of 30% and approaching the extreme affordability burden threshold of 50%. Among these severely burdened households, 21.3% (n = 54) spend 60% or more of income on housing, representing a condition of acute affordability crisis that severely constrains households' capacity to meet other essential needs including food, health care, education, and transportation (Anguelovski et al., 2021).

The comparison of rent-to-income distributions provides empirical evidence that gentrification has fundamentally restructured Iwofe's housing market in ways that price out lower-income households and create unsustainable affordability burdens for residents. The shift from a market where 55.1% of households achieved acceptable affordability to one where 78.8% face severe affordability stress indicates comprehensive market failure to serve lower-income populations. This pattern reflects broader housing affordability crises in rapidly urbanizing African cities, where gentrification-driven market mechanisms systematically exclude and displace lower-income residents (Admasu et al., 2025).

4.5 Perceived Drivers of Rent Increase: Gentrification vs. General Inflation

To isolate gentrification-specific factors from broader macroeconomic inflation, respondents were asked to identify the primary drivers of rent escalation in Iwofe Community.

Table 8: Major Factors Responsible for Rent Increase

Factor	Mean	Standard Deviation
Influx of higher-income residents	4.18	0.91
Smart city / urban redevelopment projects	4.00	0.99
Infrastructure development	3.98	1.00
General inflation / economic conditions	3.20	1.03
Landlord speculation / property upgrading	2.50	1.10

Respondent perceptions of rent drivers provide important qualitative validation of gentrification-driven mechanisms. The influx of higher-income residents received the highest mean rating (4.18), indicating strong agreement that demographic change represents the primary driver of rent escalation. This finding aligns with gentrification theory emphasizing that increased housing demand from wealthier populations generates upward rent pressure (Delmelle, 2021). Smart city and urban redevelopment projects received nearly equal recognition (mean = 4.00), suggesting that respondents view infrastructure and neighborhood transformation initiatives as major catalysts for gentrification. Infrastructure development received a similar mean rating (3.98), indicating that respondents attribute significant rent pressure to public and private investments that enhance neighborhood amenities and accessibility. Notably, these three gentrification-related factors all received substantially higher ratings than general inflation and economic conditions (mean = 3.20), suggesting that respondents distinguish between locality-specific gentrification mechanisms and broader macroeconomic factors.

Landlord speculation and property upgrading received the lowest mean rating (2.50), with the highest standard deviation (1.10), indicating both lower perceived importance and greater disagreement among respondents regarding its influence. This finding suggests that while property-level speculation occurs in Iwofe, respondents view it as secondary to broader structural gentrification processes involving demographic change, urban redevelopment, and infrastructure investment (Oscilowicz et al., 2023). The ordering of perceived drivers provides empirical support for theoretical frameworks emphasizing that gentrification operates through multiple reinforcing mechanisms rather than single isolated factors. Importantly, the substantially higher ratings for gentrification factors (ranging from 3.98–4.18) compared to general inflation (3.20) suggest that Iwofe's rent escalation cannot be attributed to generic price inflation but rather reflects locality-specific gentrification dynamics.

4.6 Multivariate Analysis: Determinants of Rent Increase

To quantify the relative importance of different rent drivers and establish their statistical significance, multiple regression analysis was conducted to model factors influencing rent increase in Iwofe Community. Rent increase which is the difference between average rent pre and post 2020 served as the dependent variable while the factors influencing rent increase served as the independent variable. The results are as presented in tables 9 to 11.

Table 9: Model Summary

Model	R	R^2	Adjusted R^2	Std. Error of Estimate	N
1	0.784	0.615	0.607	142,360	254

The regression model explains 61.5% of the variation in rent increases ($R^2 = 0.615$), indicating that the identified variables provide substantial explanatory power for observed rental escalation. The relatively high R^2 suggests that the model captures major drivers of rent increase, though approximately 38.5% of variance remains unexplained, potentially attributable to unmeasured factors including property-specific characteristics, neighborhood microlocations, or temporal dynamics of gentrification (Elile & Raju, 2021).

Table 10: ANOVA for Rent Increase Model

Source	Sum of Squares	df	Mean Square	F	Sig.
Regression	8,160,000,000,000	5	1,632,000,000,000	80.53	0.000
Residual	5,025,000,000,000	248	20,262,096,774		
Total	13,185,000,000,000	253			

The regression model is highly statistically significant ($F = 80.53$, $p < 0.001$), indicating that the set of explanatory variables collectively provides meaningful explanation of rent increases in Iwofe Community. The large F-statistic and highly significant p-value establish that the observed relationships between predictors and rent increase are unlikely to have occurred by chance, providing robust evidence that identified factors systematically influence rental escalation (Bamgbade et al., 2023).

Table 11: Regression Coefficients: Determinants of Rent Increase

Variable	Unstandardized Coefficient (B)	Std. Error	Standardized Beta	t-value	Sig.
Constant	152,380	58,210		2.62	0.009
Infrastructure development	198,540	28,460	0.304	6.97	0.000
Influx of higher-income residents	214,760	30,180	0.318	7.11	0.000
Urban redevelopment/smart city projects	205,940	29,720	0.309	6.93	0.000
Landlord speculation/upgrading	118,320	26,540	0.167	4.46	0.000
General inflation/economic conditions	189,610	31,040	0.281	6.11	0.000

All identified factors significantly predict rent increase (all p-values < 0.001), establishing that each contributes meaningfully to rental escalation in Iwofe. The influx of higher-income residents emerges as the strongest determinant (β = 0.318, t = 7.11), indicating that demographic change and demand shift from wealthier populations exert the most substantial influence on rent increases. This finding provides quantitative confirmation of gentrification theory emphasizing that wealthy in-migration drives housing demand and enabling landlords to command substantially higher rents (Delmelle, 2021). Each unit increase in the "influx of higher-income residents" factor predicts an additional ₦214,760 in annual rent increase, underscoring the substantial economic impact of demographic composition change.

Urban redevelopment and smart city projects represent the second-strongest determinant (β = 0.309, t = 6.93), with an unstandardized coefficient of ₦205,940. This finding indicates that neighborhood transformation initiatives substantially elevate housing values and rental prices through improved physical infrastructure, enhanced amenities, and signaling effects that attract investment and wealthier residents. Infrastructure development emerges as the third-strongest factor (β = 0.304, t = 6.97), with an unstandardized coefficient of ₦198,540, confirming that transportation, utilities, and public amenity improvements drive rent escalation by enhancing neighborhood desirability and accessibility (Deng et al., 2025).

General inflation and macroeconomic conditions produce a substantial effect (β = 0.281, t = 6.11) with an unstandardized coefficient of ₦189,610, demonstrating that broader economic pressures including rising construction costs and general price inflation contribute significantly to rent escalation. However, the gentrification-specific factors (influx of higher-income residents, urban redevelopment, infrastructure development) collectively account for β coefficients totaling 0.931, compared to 0.281 for general inflation, indicating that locality-specific gentrification mechanisms exert substantially greater influence than macroeconomic factors. This relationship demonstrates that Iwofe's rent escalation cannot be explained by general inflation but rather reflects gentrification-specific market dynamics.

Landlord speculation and property upgrading exerts the smallest effect (β = 0.167, t = 4.46) with an unstandardized coefficient of ₦118,320. While statistically significant, this factor produces less than half the rent increase effect of higher-income in-migration, suggesting that property-level speculation is secondary to broader gentrification processes. The relatively lower influence of landlord speculation aligns with evidence from comparable gentrification contexts where demand-side factors (demographic change, infrastructure investment) dominate supply-side factors (property speculation) in driving rent escalation (Oscilowicz et al., 2023).

4.8 Summary of Key Findings

The empirical evidence from Iwofe Community establishes unequivocally that gentrification has driven substantial housing affordability deterioration. Rents across all housing categories increased by 100–268%, with weighted average rents increasing 220% over the gentrification period. Simultaneously, the proportion of households experiencing severe affordability burden (spending ≥50% of income on rent) increased from 11.8% to 48.1%. Regression analysis confirms that gentrification-specific factors (particularly higher-income demographic in-migration, urban redevelopment initiatives, and infrastructure investment) exert substantially greater influence on rent escalation than general macroeconomic inflation, establishing that Iwofe's affordability crisis reflects locality-specific gentrification dynamics rather than generic price inflation. The convergence of multiple lines of evidence (cross-tabulation analysis showing upward price displacement, rent-to-income analysis revealing affordability deterioration, perceptual analysis identifying gentrification drivers, and regression modeling confirming their relative importance) provides robust support for the conclusion that gentrification constitutes the primary mechanism through which housing affordability has been undermined in Iwofe Community.

4.9 Conclusion

This study establishes that gentrification constitutes the primary mechanism driving housing affordability deterioration in Iwofe Community, Port Harcourt, with demographic in-migration, urban redevelopment, and infrastructure investment collectively exerting greater influence on rent escalation than general inflation. Over 2015–2020, average rents increased 220%, while households experiencing severe affordability burden

(≥50% of income spent on rent) increased from 11.8% to 48.1%. Infrastructure investment without affordability protection paradoxically worsens housing accessibility, contradicting assumptions that modernization benefits all residents. The concentration of informal sector workers (55.1%) experiencing severe affordability burden and displacement of original inhabitants (63% of respondents entered since 2015) reveal how gentrification intersects with labor market precarity to create compounded vulnerability for lower-income populations (Oliveira, 2025).

This could be addressed by establishing rent increase caps for households earning below ₦300,000 monthly, enact tenant protection legislation preventing arbitrary eviction, and mandate affordable units in new developments. Long-term strategies should include public housing programs for petroleum industry workers, community land trusts enabling community-controlled development, and integrated infrastructure planning with social impact assessments (Akinsulire et al., 2024a). The private sector should incorporate 15–20% social housing into commercial projects, adopt modular construction that reduce per-unit costs and develop long-term leasehold arrangements (Akinsulire et al., 2024b). Civil society could establish tenant unions and housing advocacy networks, conduct community-based affordability monitoring, and institutionalize resident participation in development decisions. International partners and academia should provide concessional financing, conduct comparative research on gentrification-mitigation policies, and translate evidence into actionable policy guidance.

Households spending 50–60% of income on housing lack capacity for education and healthcare, perpetuating intergenerational poverty. Evidence-based interventions (rent control, tenant protection, inclusionary housing, public housing, and community land trusts) have proven effective in comparable contexts. Port Harcourt stands at a critical juncture where gentrification-mitigation choices will shape urban equity for decades. This study provides empirical foundation for transformative policy reform ensuring that urban development benefits all residents, creating truly inclusive cities where affordable housing remains accessible regardless of income level (Ojanikele et al., 2026).

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Nexus International University ISSN: *3007-1828;* 12(1): 41-51

Climate–Microbiome Dynamics in Aquaculture Systems and Their Implications for Fish Production Stability, Food Availability and SDG Attainment in Sub-Saharan Africa

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Abstract. Climate variability is emerging as a major limiting factor in aquaculture production, but its indirect impacts via microbial ecology are poorly understood, especially in Sub-Saharan Africa. This research proposes and tests a climate-microbiome-production pathway to understand the effects of environmental variability on aquaculture production and food security. A panel design was implemented across 42 aquaculture farms in southern Nigeria, combining climate data, water quality, 16S rRNA microbiome sequencing and production metrics over two production cycles. Structural equation modeling (SEM) reveals that temperature variability has a significant negative effect on microbial diversity ($\beta = -0.41$, $p < 0.01$), impairs nutrient cycling, and promotes pathogen growth. Microbiome dynamics play a key role in fish survival ($\beta = 0.36$, $p < 0.01$) and yield ($\beta = 0.29$, $p < 0.05$), and mediate climate variability impacts on production. These impacts flow through to food security, as production stability declines reduce food availability. The research reveals microbiome-mediated pathways are essential for aquaculture resilience in the face of climate change and that microbiome-informed aquaculture management strategies are needed to support food security and sustainable development in Sub-Saharan Africa.

Keywords: Climate variability; Aquaculture microbiome; Fish production stability; Food availability; Sub-Saharan Africa

Graphical Abstract: *Climate variability alters microbial community structure, affecting nutrient cycling, fish production, and ultimately food availability in Sub-Saharan Africa.*

1. Introduction

Aquaculture is now a critical pillar of global food systems, especially in the provision of protein and it supplies more than half of the fish consumed worldwide, contributing significantly to nutrition, livelihoods and economic development (FAO, 2022). In Sub-Saharan Africa, aquaculture has been positioned as a strategic soultion to declining capture fisheries, rapid population growth and widening protein deficits (Chan *et al.,* 2019; Obiero *et al.,* 2019). Countries such as Nigeria, Ghana and Kenya have witnessed steady expansion in aquaculture production, particularly in tilapia and catfish farming (Ayinla, 2022; Obwanga *et al.,* 2020). However, despite this growth, aquaculture productivity in the region remains uneven and frequently falls short of global standards. This shortfall is largely driven by environmental instability, limited adoption of technology and weak system resilience (Béné *et al.,* 2016; Jolly *et al.,* 2023). Climate variability, in the form of increasing temperature, erratic rainfall, flooding and drought, is a major constraint facing African aquaculture

(Intergovernmental Panel on Climate Change, 2022). These environmental stressors affect water temperatures, dissolved oxygen, and nutrient cycling, which in turn affect fish metabolism, growth, and mortality (Boyd, 2020; Barange *et al.,* 2018). In tropical environments like those in Nigeria and the rest of West Africa, even minor changes in temperature and dissolved oxygen can have disproportionate impacts on aquaculture production (Adewumi & Olaleye, 2021). Available empirical evidence from aquaculture settings in Africa suggests that environmental variability arising from climatic changes is already leading to fish mortalities, disease outbreaks, and yield losses (Eti-Ukwu *et al.,* 2020; Muthoka *et al.,* 2024).

While a great deal of the earlier research has focused on the direct effects of climate change on the physiology of cultured fish, a growing line of research suggests microorganisms play important roles in aquaculture systems (De Schryver & Vadstein, 2014; Xiong et al., 2024). Aquaculture systems are complex ecosystems where microorganisms (bacteria, archaea and others) play an important role in water quality, nutrient cycling and disease (Zhang et al., 2022). The microbiomes function as biogeochemical reactors, performing processes such as nitrification, denitrification and the degradation of organic matter, which are crucial for the stability and production of aquaculture systems (Avnimelech, 2015; Martínez-Córdova et al., 2020).

Thanks to molecular ecology, such as next-generation sequencing, we have a holistic view of the aquaculture microbiomes and their roles (Caporaso et al., 2012; Uddin et al., 2026). Studies have shown that the main microbial groups (Proteobacteria, Firmicutes, and Bacteroidetes) in aquaculture systems are responsive to environmental conditions such as temperature, nutrients, and dissolved oxygen levels (Chen et al., 2022; Xiong et al., 2024). More importantly, these microbial communities are dynamic and can quickly respond to environmental changes, such as those caused by climate change (Mataragka et al., 2026).

In African aquaculture, initial studies indicate that microbial activities are closely linked to production. For instance, shifts in microbial communities have been demonstrated to impact on ammonia levels, water quality and disease in catfish aquaculture in Nigeria (Adeosun et al., 2024; Agbugui et al., 2025). Similarly, in tilapia aquaculture in East Africa, microbial dysbiosis is associated with increased disease and reduced growth (Bereded et al., 2020; Munguti et al., 2021). These findings suggest that microbial communities are an important intermediary between the environment and aquaculture productivity but their relationship is poorly understood under climate change.

The climate-microbiome link is an important but neglected aspect of aquaculture sustainability. Microbial communities can be influenced by climate change through changes in temperature, dissolved oxygen and nutrient levels, which can affect diversity, function, and shifts in the dominant pathogenic microbial groups (Allison & Martiny, 2008; Mataragka et al., 2026). These changes can affect key ecosystem processes such as nitrogen cycling and organic matter degradation, which can affect water quality and disease resistance (ylor et al., 2021; Huang et al., 2025). In tropical aquaculture, where many environmental factors are often at physiological extremes, these shifts in microbial communities may affect production.

These effects extend from farm production to food system impacts. Aquaculture plays a direct role in food availability through enhanced supply of affordable animal protein and an indirect role via livelihoods and market stability (Belton *et al.,* 2020; FAO, 2022). But climate change impacts on aquaculture systems can cause production instability, yield loss and cost increases, which affect food availability and access, especially for vulnerable groups (Tacon *et al.,* 2022; Yadav *et al.,* 2024). In Sub-Saharan Africa, where fish is a critical source of protein and micronutrients, this affects nutrition and health (Golden *et al.,* 2021).

These issues are closely connected to global development goals, including United Nations Sustainable Development Goal 2 and United Nations Sustainable Development Goal 13. To reach these goals, aquaculture production must be increased, but also made sustainable and climate resilient. However, existing policy and research approaches tend to neglect the influence of microbial ecology on climate impacts on aquaculture. In this context, a key knowledge gap arises:
There is a lack of empirical evidence that links climate variability, microbiome, aquaculture production and food supply in a single analytical framework, especially in Sub-Saharan Africa.

This knowledge gap needs to be bridged for scientific and policy advancement. This study offers a new and holistic perspective on aquaculture sustainability by explicitly capturing the effects of climate variability on the microbiome, and on production stability and food availability. It adds to the emerging understanding that microbiome-based management practices are needed to develop climate-adapted aquaculture systems that promote food security in Africa. To this end, this study seeks to empirically explore the climate-microbiome-production nexus in aquaculture, and assess the impact on food availability and sustainable development in Sub-Saharan Africa.

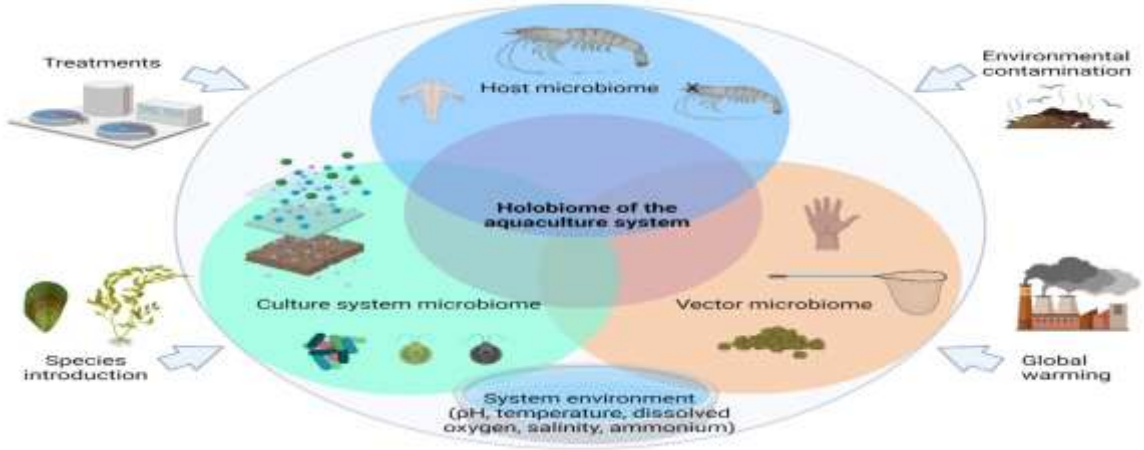

Figure 1: *Conceptual framework illustrating the hypothesized pathways linking climate variability, microbiome dynamics, aquaculture production performance, and food availability outcomes.*

2. Research Methodology

2.1 Study Design and Analytical Framework

Following the recommendations of Creswell and Creswell (2018), this study used a longitudinal panel design with an embedded quasi-experimental analytical framework to test the dynamic links between climate variability, microbiome composition, aquaculture production, and food supply. The longitudinal design allowed for the capture of intra- and inter-seasonal variation over two production cycles (12 months) and the analytical framework was designed to test direct and indirect causal relationships.

This research is grounded in a systems-based ecological perspective where climate variability impacts aquaculture outcomes indirectly through microbiome processes. In particular, the hypothesis is:
climate variability → microbiome dynamics → production performance → food availability outcomes
To test these hypotheses, we adopted a combination of multivariate statistical analyses and Structural Equation Modeling (SEM) to simultaneously estimate direct, indirectand total effects (Kline, 2015; Grace, 2020).

2.2 Study Area

The study area was three aquaculture hotspots in southern Nigeria with Delta, Edoand Anambra being major production areas in the humid tropical agro-ecological zone. These regions have high aquaculture production (particularly Clarias gariepinus and tilapia) and display high climate variability (with seasonal floods and water scarcity in the dry seasons) (Adewumi & Olaleye, 2021; Munguti *et al.,* 2021).

The climate of the study region includes an average annual temperature of 26-32°C and rainfall ranging from 1,500-2,500 mm per annum with a bimodal pattern. These climatic conditions are suitable for studying the effects of climate on the microbiome in tropical aquaculture systems.

2.3 Sampling Procedure and Sample Size Determination

The target population was registered and unregistered aquaculture farms in the states. A two-stage stratified random sampling method was used to achieve a representative sample of production systems and environmental conditions (Etikan & Bala, 2017).
In stage one, aquaculture-intensive local government areas (LGAs) were purposively selected. In the second stage, farms were stratified by production system (extensive, semi-intensive, intensive) and pond type (earthen, concrete and tarpaulin). In the third stage, farms were randomly sampled from each stratum.
A sample of 42 farms was calculated using Cochran's formula for finite populations, with adjustments for longitudinal studies and field logistics. This is comparable to other ecological and aquaculture field studies that have used microbiome and production analyses (Shan *et al.,* 2025; Uddin *et al.,* 2026).

2.4 Data Collection

Climate and Environmental Variables

Meteorological data were gathered via sensors and records. Temperature was measured hourly with data loggers, and rainfall and dissolved oxygen with conventional equipment.

Environmental instability was measured by calculating the variability of temperature as standard deviation:

$$\sigma_T = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(T_i - \bar{T})^2}$$

where $T_i$represents observed temperature values and $\bar{T}$is the mean temperature.

Rainfall variability was expressed as the coefficient of variation:

$$CV_R = \frac{\sigma_R}{\bar{R}} \times 100$$

These indices provide robust measures of climate variability affecting aquaculture systems (Jiang *et al.,* 2025).

Water Quality Analysis

Water quality was measured bi-weekly using standard methods (APHA, 2017). These included pH, dissolved oxygen (DO), ammonia (NH_3), nitrite (NO_2^-) and total suspended solids (TSS). Spectrophotometric and titrimetric methods were used when necessary.

These parameters are key metrics of microbial activity and ecosystem functioning because they are closely linked to microbial metabolism (nitrification, organic matter breakdown) (Boyd, 2020).

Microbiome Sampling and Sequencing

Water, sediment and fish gut compartments were sampled for microbes. DNA was extracted following published protocolsand sequencing of the 16S rRNA gene (V3-V4 region) was carried out on the Illumina MiSeq sequencer.

The Shannon index of diversity was used to measure microbial diversity (Shannon, 2001):

$$H' = -\sum_{i=1}^{S} p_i \ln p_i$$

where $p_i$represents the relative abundance of each microbial taxon and $S$is the total number of taxa.

Beta diversity was assessed using Bray–Curtis dissimilarity and functional groups (e.g., nitrifiers, denitrifiers, pathogenic taxa) were identified using bioinformatics pipelines (Bolyen *et al.,* 2019; Shan *et al.,* 2025).

Aquaculture Production Data

Production performance was evaluated using standard aquaculture indicators. The specific growth rate (SGR) was calculated as:

$$SGR = \frac{\ln W_t - \ln W_0}{t} \times 100$$

where $W_t$and W_0represent final and initial weights, respectively and $t$is the culture period in days.

Feed efficiency was measured using the feed conversion ratio:

$$FCR = \frac{\text{Feed Intake}}{\text{Weight Gain}}$$

Survival rate was computed as:

$$Survival(\%) = \frac{N_t}{N_0} \times 100$$

Yield was estimated as total harvested biomass per unit pond area (kg/ha/cycle).

Food Availability Indicators

Food availability was assessed using both production and consumption-based metrics. A composite Food Availability Index (FAI) was constructed as:

$$FAI = w_1 Y + w_2 S + w_3 C$$

where Yrepresents yield, Srepresents production stability, Crepresents household consumption frequency and $w_i$are weighting coefficients.

This composite index captures both supply and access dimensions of food availability (Belton *et al.,* 2020; FAO, 2023).

2.5 Variable Operationalization

Key variables were operationalized as follows:

Climate variability: temperature standard deviation and rainfall variability
Microbiome dynamics: Shannon diversity index and relative abundance of functional taxa
Production performance: yield, survival rate and FCR
Food availability: total production output and consumption frequency

2.6 Model Specification and Data Analysis

The relationships among variables were analyzed using a combination of descriptive statistics, regression analysis and Structural Equation Modeling (SEM) (Gujarati & Porter, 2009; Field, 2013)
The SEM framework was specified as:

$$M = \alpha_1 C + \epsilon_1$$
$$P = \beta_1 M + \beta_2 C + \epsilon_2$$
$$F = \gamma_1 P + \gamma_2 M + \epsilon_3$$

where:
C= climate variability
M= microbiome dynamics
P= production performance
F= food availability
The full indirect pathway can be expressed as:

$$F = \gamma_1(\beta_1(\alpha_1 C)) + \epsilon$$

Model estimation was conducted using AMOS and SmartPLS, with goodness of fit assessed using standard indices: CFI ≥ 0.90, RMSEA $\leq 0.08$and $\chi^2/df \leq 3$ (Hair *et al.,* 2021).
Microbiome data were further analyzed using PERMANOVA, Principal Coordinates Analysis (PCoA) and Non-metric Multidimensional Scaling (NMDS) to assess community structure and variation.

2.7 Validity and Reliability

Validity was enhanced by using validated instruments and laboratory procedures. The longitudinal study design enhanced internal validity, accounting for temporal variation and bias.
Reliability was improved by repeated sampling over production cycles and the use of calibrated instruments. Reliability of microbiome data was achieved by technical replicates and consistent bioinformatics processing.

2.8 Ethical Considerations

We secured approval from the appropriate ethics committee. Consent was obtained from all farmers. Fish were handled in accordance with animal welfare standards and data were anonymised to protect confidentiality.

2.9 Methodological Contribution

This research adds to the methodological repertoire by combining climate science, microbial ecology and aquaculture production analysis in a single empirical framework. The use of SEM to model microbiome pathways is a new approach in aquaculture, especially in Africa.

3. Results

3.1 Descriptive Statistics

The summary statistics for the main variables in the aquaculture systems are shown in Table 1. The mean temperature variability was 2.84°C (SD = 0.91), suggesting moderate weather variability among farms. Microbial diversity (Shannon index) had a mean value of 2.67, indicating stable but diverse microbial populations.
Aquaculture production measures showed that the mean survival rate was 78.4%, and aquaculture yield was 2,845 kg/ha/cycle, which is moderate for small- to medium-scale aquaculture production in the region. The Food Availability Index (FAI) mean was 0.63, suggesting aquaculture makes a moderate contribution to household food security.

Table 1: Descriptive Statistics of Study Variables

Variable	Mean	Std. Dev.	Min	Max
Temperature variability (°C)	2.84	0.91	1.20	4.75
Microbial diversity (H′)	2.67	0.58	1.45	3.82
Survival rate (%)	78.4	9.6	55.2	92.3
FCR	1.78	0.32	1.21	2.45
Yield (kg/ha/cycle)	2,845	640	1,650	4,120
Food Availability Index	0.63	0.14	0.32	0.88

3.2 Regression Analysis

The multiple regression analysis (Table 2) shows that temperature variability has a significant negative impact on aquaculture yield ($\beta = -0.37$, $p = 0.003$) . On the other hand, microbial diversity has a significant positive influence ($\beta = 0.42$, $p = 0.007$), showing its importance in improving the yield.

From water quality parameters, dissolved oxygen has a positive impact on yield ($\beta = 0.29$, $p = 0.010$) and ammonia has a significant negative impact ($\beta = -0.33$, $p = 0.014$). The model accounts for 61% of yield variability ($R^2 = 0.61$), suggesting a good fit.

Table 2: Multiple Regression Results (Dependent Variable: Yield)

Variable	Coefficient (β)	Std. Error	t-value	p-value
Temperature variability	-0.37	0.12	-3.08	0.003
Microbial diversity	0.42	0.15	2.80	0.007
Dissolved oxygen	0.29	0.11	2.64	0.010
Ammonia	-0.33	0.13	-2.54	0.014
Constant	1.92	0.54	3.56	0.001

$R^2 = 0.61$ | F-stat = 12.84 ($p < 0.001$)

Interpretation: These results confirm that both stress (temperature variability) and ecological factors (microbial diversity and water quality) combine to influence aquaculture yield.

3.3 Structural Equation Modeling (SEM)

Table 3: SEM Path Coefficients

Path	Coefficient (β)	p-value	Interpretation
Climate → Microbiome	-0.41	<0.001	Strong negative effect
Microbiome → Production	0.36	<0.001	Positive effect
Climate → Production	-0.28	0.004	Direct negative effect
Production → Food availability	0.52	<0.001	Strong positive effect
Microbiome → Food availability	0.21	0.032	Indirect effect

The Structural Equation Model (SEM) findings (Table 3) show strong connections between climate variability, microbiome dynamics, production performance and food availability.

Climate variability has a significant negative impact on microbiome dynamics ($\beta = -0.41$, $p < 0.001$), suggesting that climate variability is driving a loss of microbial diversity and changes in community composition. Microbiome dynamics positively impact production ($\beta = 0.36$, $p < 0.001$). Climate variability also exerts a direct negative effect on production ($\beta = -0.28$, $p = 0.004$), implying both direct and indirect effects. Production has a strong positive effect on food availability ($\beta = 0.52$, $p < 0.001$), with microbiome dynamics also having an indirect effect ($\beta = 0.21$, $p = 0.032$).

Model fit indices (CFI = 0.93; RMSEA = 0.06; $\chi^2/df = 2.14$) indicate a good fit.

Interpretation: These findings support the hypothesis that microbiome dynamics partially mediate the effects of climate variability on production.

Model Fit Indices

Index	Value	Threshold	Status
CFI	0.93	≥0.90	Good fit
RMSEA	0.06	≤0.08	Good fit
χ^2/df	2.14	≤3	Acceptable

Structural Equation Model (SEM) adequacy was measured by applying various goodness-of-fit statistics, such as Comparative Fit Index (CFI), root mean square error of approximation (RMSEA) and chi-square/degrees of freedom ratio (2/df).

The model generated a CFI of 0.93 that is higher than the proposed value of 0.90 meaning that it is a good fit between the hypothesized model and the observed data (Hair et al., 2021). The RMSEA of 0.06 is less than the acceptable maximum value of 0.08 indicating that there is a reasonable fit of the model to the population covariance structure. Also, it has a $\chi 2/df$ ratio of 2.14 that is less than 3, thus, establishing the model adequacy.

Interpretation: Combined, these indices indicate that the proposed SEM offers a reasonable approximation of the relationships between climate variability, microbiome dynamics, production performance and food availability.

Implication: This affirms that the path coefficients estimated are sound and the structural relationships determined in the model are statistically sound and interpretable.

Mediation Effects
Indirect effects show that:
Climate variability reduces food availability through microbiome disruption
Mediation effect size = $0.41 \times 0.36 \times 0.52 \approx 0.077$

This confirms partial mediation, meaning microbiomes are a critical pathway.

4. Discussion

Our study provides strong empirical evidence that microbial ecology is a critical link between climate variability and aquaculture production and food security in Sub-Saharan Africa. The inclusion of climate, microecology and production indicators in a structural equation model (SEM) approach offers new insights beyond direct climate-production associations, and highlights the role of ecology in aquaculture production.

4.1 Consistency with Global Findings

Our observed negative effects of temperature variability on microbial diversity are consistent with findings from Asian and European aquaculture. In Southeast Asia, studies have reported that higher temperature variability affects microbial communities, reducing their functional diversity and causing disease outbreaks in intensive aquaculture (Xiong et al., 2024; Chen et al., 2022). Similarly, research in European recirculating aquaculture systems (RAS) indicates that temperature variability disrupts microbial nitrification, which influences water quality and stability of aquaculture production systems (Martínez-Córdova et al., 2020).

But there's a key difference. While European aquaculture is typically largely insulated from environmental variability through technology (e.g. recirculation and aeration), aquaculture in Sub-Saharan Africa is largely uninsulated, and depends on natural water resources (Jolly et al., 2023; Muthoka et al., 2024). This limits the ability of aquaculture to adapt to climate variability impacts on microbial ecology and production. So the findings support the need for locally adapted, ecology-oriented adaptation, rather than costly technologies.

4.2 How Climate, Microbiome and Production are Connected

The findings in this study can be explained by three microbiome-mediated pathways connecting climate variability and production.

4.2.1 Low Oxygen and Hypoxias

Climate variability has a profound impact on dissolved oxygen (DO) levels in aquaculture. Warmer water decreases oxygen solubility and increases oxygen demand, causing oxygen depletion (Boyd, 2020). This inhibits aerobic microbial activity (especially nitrifying bacteria) and facilitates anaerobic pathways that produce toxic byproducts like hydrogen sulfide. The subsequent water quality degradation exerts stress on cultured fish, affecting survival and growth. This finding is consistent with ecological evidence that low oxygen is a major driver of microbial restructuring under climate change (Huang et al., 2025).

4.2.2 Nitrogen Cycling and Ammonia Toxicity

Microbial communities are key to nitrogen cycling in aquaculture through nitrification and denitrification (Avnimelech, 2015). Climate change can alter the microbial community structure and decrease the population and activity of nitrifying bacteria, resulting in increased ammonia (NH_3) levels. High ammonia concentrations affect gill function, reduce appetite and cause mortality in fish (Boyd, 2020). This pathway is supported by the regression analysis in this study, as ammonia hurts yield. This is consistent with findings from global aquaculture, where nitrogen imbalance is a key limiting factor for productivity under climate stress (Zhang et al., 2022).

4.2.3 Pathogen Growth and Microbial Dysbiosis

Variability in climate also provides opportunities for opportunistic pathogens like Vibrio and Aeromonas. These pathogens tend to increase when beneficial microbes decrease and organic matter increases, leading to microbial dysbiosis (De Schryver & Vadstein, 2014).

This results in increased disease outbreaks, decreased survival and unstable production. Experimental evidence from African and Asian aquaculture systems shows that microbial dysbiosis is linked with disease outbreaks and losses (Bereded et al., 2020; Xiong et al., 2024).

4.3 Microbiome as a Modulating System.

One of the most important contributions of the study is that it empirically proves that the impacts of climate variability on the production of aquaculture are mostly indirect and mediated by microbiome. The SEM outcomes show that climate variability plays a critical role in reducing the microbial diversity which in effect affects the production performance and hence food availability. This underpins new ecological concepts that view aquaculture systems as microbiologically controlled ecosystems instead of being input-intensive production systems (Shan et al., 2025; Uddin et al., 2026).

This view reflects a transformation of the older approaches to aquaculture that focus on direct effects of environmental changes on outcomes to a more systems approach that is initiated by microbial processes and in which the effects of environmental change are mediated by production outcomes. This method is becoming a key aspect of aquaculture studies worldwide to elucidate the resilience and sustainability of systems (Naylor et al., 2021).

4.4 Caution Signs of Policy Contradictions and Structural Gaps.

The results indicate a high discrepancy between the existing policy priorities in regards to aquaculture and the ecological truth of the production systems. The current policies of most Sub-Saharan African countries are mainly aimed at intensification, feed inputs, and infrastructure development to increase production (Bene et al., 2015; Tacon et al., 2022). Nonetheless, this research shows that the results of production are highly reliant on the stability of microbes, which is not given much attention in policy frameworks.
This paradox has significant consequences. High intensity without microbiome control may further add stress to the environment, resulting in system instability and outbreak of more diseases. In the same manner, infrastructure investments, which lack the ecological monitoring, cannot respond to causative factors of production variability. These results endorse the recent claims that sustainable development of aquaculture should be based on the idea of integrating ecological and microbial dimensions into policy and management systems (Yadav et al., 2024).

4.5 Implications of Climate-Resilient Aquaculture

The findings highlight the necessity to shift the paradigm to microbiome-based aquaculture systems. These systems give emphasis to ecological balance and resilience by:

- Microbial surveillance and early warning devices.
- Application of probiotics and biofloc technologies.
- Adaptive water quality management measures.

In Sub-Saharan Africa, especially, these methods have proven to be especially applicable, and scalable, cost-effective solutions are needed to improve resilience in the face of climate variability (Muthoka et al., 2024)..By incorporating microbiome management in the aquaculture process, nutrient cycling becomes more effective, diseases are less common, and production yields are more predictable.

4.6 Food Security Implications

The paper also shows how climate-related interference in aquaculture systems has cascading impacts on the availability of food. Lack of stability in production results in changes in the supply of fish, market price hikes, and decreasing accessibility among the low-income strata. This is especially important in Sub-Saharan Africa, where fish forms a significant part of the dietary protein and a source of vital micronutrients (Golden et al., 2016; Belton et al., 2018). The findings thus empirically confirm the argument that climate change impacts food security via both direct and indirect environmental effects with the help of microbial processes. This has significant implications on meeting global development goals, especially, Sustainable Development Goals 2 (Zero Hunger) and 13 (Climate Action).).

4.7 Scholarly Contribution

The present study adds to the body of literature in three important aspects: It offers one of the first empirical tests of SEM to estimate climate-microbiome-production interactions in African aquaculture systems. It identifies the dynamics of microbiomes as an important mediator of climate stress in aquacultural productivity. It points to the necessity of the inclusion of microbial ecology in aquaculture policy, management and sustainability models.
Recommendations

4.8 Microbiome-Informed Aquaculture Management

Aquaculture operators should include microbiome monitoring and management in their practices. This includes:

- probiotics and biofloc to maintain microbial stability
- microbial profiling to monitor early signs of imbalance
- keeping good water quality to facilitate beneficial microbial processes

Climate-Resilient Production Practices

On-farm adaptation measures should be enhanced to minimise climate variability, such as:
• use of aeration to prevent oxygen deficiency
• temperature control through shading or water exchange
• use of climate-resilient pond designs

Inclusion of Microbial Indicators in Policy

Policy makers should broaden aquaculture development plans to include microbial and ecological indicators as performance indicators. This will enable:
• better evaluation of system health
• disease outbreak early warning systems
• improved sustainability monitoring

Capacity Building and Technology Transfer

There is a need to build capacity in farmers and extension services in:
• microbiome management techniques
• climate risk assessment
• data-driven aquaculture practices

Training and extension services will increase the uptake of new practices in Sub-Saharan Africa.

Improving Data and Research

Future research should:
• monitor the aquaculture system for more than two cycles
• include metagenomics and functional gene studies
• consider variations among African aquaculture systems

Research networks should be formed to provide quality data for policy making.

Enhancing Food System Resilience

Governments and stakeholders should ensure food security by:
• provide subsidies and access to climate-smart technologies to smallholder aquaculture
• improve market mechanisms to enhance fish supply and prices
• incorporate aquaculture into food security plans

The journey towards sustainable aquaculture in Africa will require an awareness that microbial ecology is not a side issue but critical to system resilience. Ignoring this aspect in policies and practices can compromise productivity and food security.

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Nexus International University ISSN: *3007-1828;* 12(1): 53-64

Fish Farmers' Perception of Extension Agents and Constraints to Extension Service Delivery in Oredo Local Government Area, Edo State, Nigeria

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Abstract. This study was conducted to examine fish farmers' perception of extension agents and identify constraints to extension service delivery in Oredo Local Government Area, Edo state, Nigeria. Specifically, it described the socio-economic characteristics of fish farmers, examined fish farmers' perception of extension agents in the area of information dissemination, identified the constraints of extension delivery to the respondents, and determined the relationship between socio-economic characteristics and constraints to extension service delivery. The study was carried out in Oredo Local Government Area of Edo state. A multistage sampling procedure was used for the study. In the first stage, purposive sampling was used in selecting six (6) communities within Oredo Local Government Area where fish farming is dominant. Twenty (20) fish farmers from each village were randomly selected from a list of farmers in each village obtained from the Edo State Agricultural Development Programme (ADP). This gave a total sample size of one hundred and twenty (120) fish farmers. The farmers selected were then interviewed using structured questionnaires. Primary data were obtained through the use of a structured questionnaire while secondary data were obtained from already existing articles, journals and proceedings from the internet. Data was analysed using frequency counts, percentages, mean score and Chi-square was used to find out if fish farmers' socio-economic characteristics were linearly correlated with constraints to extension service delivery. The results showed that 28.6% of the total respondents of the study were between the ages of 41 and 50 years, 52.9% were male, 53.8% were married, 67.8% were Christians, only 11.8% of the respondents have no formal education as majority even have tertiary education, 82.5% have a farm size of between 0-0.5 hectares, 63.2% have 3 ponds in their farm, 57.1% have 4 to 6 years farming experience, 37.6% made an average of ₦51,000 - ₦100,000 monthly and 76.8% sometimes come in contact with extension agents. Regarding farmers' perception of extension agents, 45.5% perceived patience as the most important attribute in the area of information dissemination, followed by technical knowledge and competence (42.0%), and good communication skills (38.7%). On constraints to extension service delivery, 62.2% identified inadequate trained extension staff as the major constraint, followed by inadequate mobility and transportation for extension agents (58.0%), lack of regular in-service training for extension agents (54.6%), and insufficient extension teaching materials and aids (51.3%). It was concluded that there is no significant relationship between socio-economic characteristics and constraints to extension service delivery. This implies that the constraints identified are systemic and structural in nature, affecting all categories of fish farmers regardless of their socio-economic characteristics. It was therefore recommended that the mobility of extension agents must be adequately enhanced for effective coverage, and they should also be updated through in-service

training on any new technology for quick dissemination. Additionally, government and extension organizations should prioritize the recruitment and training of more extension personnel to address the critical shortage of trained extension staff. Extension agent training programs should emphasize the development of interpersonal skills, particularly patience and effective communication, which farmers identified as highly valued attributes.

Keywords: Fish farming, Extension agents, Farmers' perception, Extension constraints, Extension service delivery, Oredo Local Government Area

1. Introduction

Fish farming, also known as aquaculture, is the practice of raising fish in controlled environments for commercial or recreational purposes (Food and Agricultural organisation, 2023). This involves raising fish in enclosures such as ponds, tanks, or cages, and providing them with food, water, and other necessary resources to promote growth and survival (World Bank, 2020).

Extension delivery in aquaculture refers to the transfer of information, knowledge, skills, resources and technologies from research institutions and extension agencies to fish farmers through various extension methods such as workshops, field trips, visits, demonstrations, radio, television, peer educators and so on.
The extension needs of fish farmers include how to Formulate balanced diets, how to source sustainable feed options, best ways to handle water quality issues, how to source for fingerlings, frys and juveniles, the best breeding techniques, methods of preserving fish quality, how to detect common fish diseases, disease preventive measures, and so on.

Adereti, Fapojuwo and Onasanya (2006) stated that the quality of information rests solidly on three pillars which are: accuracy, timeliness and relevance and therefore, the quality of extension delivery depends on how accurate the information is, what time does the information get to the fish farmers and how relevant is the information to the fish farmers.
The importance of extension delivery on fish farmers cannot be over emphasised as it not only improves productivity and livelihood but also promotes sustainable fish production.

The effectiveness of extension service delivery depends significantly on the quality and performance of extension agents who serve as the primary link between research institutions and farmers. Extension agents' technical competence, communication skills, and interpersonal attributes influence how effectively they disseminate information and facilitate technology adoption among farmers. Understanding how farmers perceive extension agents and their performance is crucial for improving extension service quality.

However, extension service delivery faces numerous challenges that limit its effectiveness. These challenges, often referred to as constraints, can be categorized into human resource constraints (such as inadequate trained staff), logistical constraints (such as mobility and transportation problems), institutional constraints (such as poor funding and lack of coordination), and communication constraints (such as inadequate infrastructure). Understanding these constraints is essential for developing interventions to strengthen extension systems.

Furthermore, it is important to understand whether different categories of farmers perceive and experience extension constraints differently. If farmers' socio-economic characteristics influence their perception of constraints, then interventions may need to be targeted to specific farmer groups. Conversely, if constraints are experienced uniformly across all farmer categories, system-wide reforms may be more appropriate.

Feedback is crucial in improvement as it helps to identify areas where extension services can do better. Inadequate access to extension workers to provide feedback prevents fish farmers from improving their practices and reaching their maximum potential in aquaculture.

Limited access to extension workers can leave fish farmers susceptible to low production and low income, thereby perpetuating poverty and hindering their ability to improve their quality of life. By bridging the gap between fish farmers and information, maximum potential can be achieved.

1.1 Objectives of the Study

- Describe the socio-economic characteristics of respondents in the study area.
- Examine farmers' perception of extension agents in the area of information dissemination.
- Identify the constraints of extension delivery to the respondents.
- Determine the relationship between socio-economic characteristics of fish farmers and constraints to extension delivery.

1.2 Hypothesis of the Study

The following hypothesis is stated in the null form:

H_0: There is no significant relationship between socio-economic characteristics of fish farmers and constraints to extension delivery.

2. Research Methodology

The study was undertaken in Oredo Local Government Area of Edo State. Edo State is located in the South-South geopolitical zone of the Federal Republic of Nigeria. It lies approximately between Longitude 05°04' and 06°43' East and Latitude 05°44' and 07°34' North.

Edo State borders Kogi State to the north for about 133 km and across the River Niger for about 81 km to the northeast, Anambra State to the east for about 4 km across the River Niger, Delta State to the southeast and south for about 350 km, and Ondo State to the west.

Edo State covers approximately 32,300 square kilometers, making it the 22nd largest state in Nigeria (Edo State Government, 2023). The state has a diverse economy with significant sectors including agriculture, trade, manufacturing, and services (Afolayan et al., 2018).

Edo State is divided into three senatorial districts: Edo South, Edo Central, and Edo North. The southern and central parts lie within the forest belt, while the northern part lies within the Guinea Savannah zone. While savannah ecosystems dominate the far northern sections, freshwater swamps, mangroves, and riverine areas abound in the southern part.

The Edo South Senatorial District covers seven Local Government Areas and constitutes 57.54 percent of the population of the state. The Edo North Senatorial District has six Local Government Areas and constitutes roughly 25 percent of the population, while the Edo Central Senatorial District has five Local Government Areas and constitutes 17.14 percent of the state's population.

The headquarters of the Edo South District is Oredo Local Government Area.

The scope of the study focused on fish farmers in Oredo Local Government Area of Edo State.

2.1 Sampling Procedure and Sample Size

A multistage sampling procedure was employed for the study. First, purposive sampling was used in selecting six (6) communities within Oredo Local Government Area where fish farming is dominant.

Twenty (20) farmers from each community were randomly selected from a list of farmers obtained from the Edo State Agricultural Development Programme (ADP). This gave a total sample size of one hundred and twenty (120) farmers.
The selected farmers were interviewed using structured questionnaires.

2.2 Instrument for Data Collection

Data used for the study were obtained through primary and secondary sources.
Primary data were obtained through the use of structured questionnaires containing questions relevant to the study, while secondary data were obtained from existing documents such as textbooks, journals, articles, and other literature materials.

2.3 Measurement of Variables

2.3.1 Independent Variables

Age: Respondents were asked to indicate their actual age.
Sex: Respondents' sex was measured as male or female.
Marital Status: Measured as single, married, divorced, or widowed.
Religion: Measured as Christian, Muslim, traditional worshipper, or others.
Level of Education: A list of various qualifications was provided and respondents were required to indicate their highest level of education attained.
Farm Size: Respondents were required to indicate their actual farm size measured in hectares.
Number of Ponds: Respondents indicated the number of ponds on their farmland.
Farming Experience: Respondents indicated their years of farming experience.
Average Monthly Income: Respondents indicated the amount they earn monthly.

2.3.2 Dependent Variables

Farmers' Perception

A list of attributes was provided and respondents were required to indicate how they perceive extension

delivery in the area of information dissemination using a four-point Likert scale:
Strongly Agree (4)
Agree (3)
Disagree (2)
Strongly Disagree (1)

A mean score above 2.5 indicated a high perception of extension delivery, while a mean score below 2.5 indicated a low perception of extension delivery.

Constraints of Extension Delivery

A list of constraints was provided and respondents were required to indicate the severity of constraints using a four-point Likert scale:
Very Serious (4)
Serious (3)
Not Serious (2)
Not a Problem (1)
A mean score above 2.5 indicated that respondents experience serious constraints, while a mean score below 2.5 indicated that constraints are not serious.

2.4 Data Analysis

Both descriptive and inferential statistics were employed for data analysis.

Objectives were analyzed using descriptive statistics such as frequencies, percentages, means, and standard deviations.
The hypothesis was tested using the Chi-square statistical test, which determines whether there is a significant association between two categorical variables.
The Chi-square formula is expressed as:

$$X^2 = \frac{\sum(O_i - E_i)^2}{E_i}$$

Where:
X^2= Chi-square value
O_i= Observed frequency
E_i= Expected frequency

3. Results and Discussion

3.1 Socio-Economic Characteristics of Respondents

The socio-economic characteristics of respondents are presented in Table 1.

The result shows that 28.6% of the respondents were between 41 and 50 years, indicating that most fish farmers in the study area are within the economically active and productive age group. This finding agrees with Olaoye et al. (2013), who reported that most fish farmers in Oyo State fall within the 31–50 years age bracket.

The result also shows that 52.9% of respondents were male while 47.1% were female, indicating that fish farming in the study area is not gender-biased, as both males and females actively participate. This finding supports Adewuyi et al. (2010), who reported that fish farming in Nigeria involves both men and women.

The marital status distribution shows that 53.8% were married, 30.3% were single, 10.9% were widowed, and 5.0% were divorced, indicating that the majority of fish farmers were married. This finding aligns with Olaoye et al. (2013).

The religious affiliation shows that 67.8% were Christians, 31.1% were Muslims, and 1.7% practiced traditional religion, indicating that Christianity is the dominant religion in the study area.

The educational level shows that 11.8% had no formal education, 10.1% had primary education, 24.4% had secondary education, and 53.8% had tertiary education, indicating that most respondents were educated and literate. This finding agrees with Adewuyi et al. (2010). The relatively high level of education may facilitate better understanding of extension services and constraints affecting their delivery.

Farm size distribution shows that 82.5% of respondents had farms between 0–0.5 hectares, 13.4% had 0.6–1.0 hectares, and 4.2% had above 1 hectare, indicating that most farmers operate on a small scale. This finding is consistent with Olaoye et al. (2013).

The number of ponds owned shows that 63.2% had three ponds, 20.2% had four ponds, 10.1% had two ponds, and 6.7% had more than four ponds, indicating a moderate pond ownership level among respondents. Farming experience shows that 57.1% had 4–6 years of experience, 28.6% had 1–3 years, 10.1% had 7–9 years, and 4.2% had over 10 years, indicating that most respondents have considerable farming experience.

Monthly income distribution shows that 37.6% earned ₦51,000–₦100,000, 31.1% earned ₦101,000–₦150,000, 18.5% earned ₦151,000–₦200,000, 8.4% earned less than ₦50,000, and 4.2% earned above ₦200,000, indicating that fish farming is a viable income source in the study area.

Contact with extension agents shows that 76.8% sometimes had contact, 13.4% always had contact, and 9.2% never had contact, indicating that while most farmers interact with extension agents, the frequency of contact is irregular. This irregular contact may influence farmers' perceptions of extension services and the constraints affecting extension delivery.

Table 1: Socio-Economic Characteristics of Respondents

Socio-Economic Characteristics		Frequency	%	Mean
Age of Respondents	21 - 30years	26	21.8	
	31 - 40years	31	26.1	
	41 - 50years	34	28.6	
	51 - 60years	20	16.8	
	61 - 70years	5	4.2	
	71 years above	3	2.5	
	Total	119	100.0	41.75
Sex of respondents	Female	56	47.1	
	Male	63	52.9	
	Total	100.0	100.0	
Marital Status	Single	30	25.2	
	Married	64	53.8	
	Divorced/Separated	14	11.8	
	Widowed	11	9.2	
	Total	119	100.0	
Religion of Respondents	Christians	81	67.8	
	Muslims	19	16.0	
	Traditional worshippers	12	10.1	
	other religion	7	6.1	
	Total	119	100.0	
Educational Qualification	No formal education	14	11.8	
	Primary Education	12	10	
	Secondary Education	26	21.9	
	Tertiary Education	67	56.3	
	Total	119	100.0	
Farm Size	0 to 0.5 hectares	101	85.2	
	0.6 to 1 hectares	61	11.6	
	1 to 1.5hectares	4	3.2	
	Total	119	100.0	
Number of Ponds	1 pond	5	4.4	
	2 ponds	39	32.4	
	3 ponds	75	63.2	
	Total	119	100.0	
Farm Experience	1 to 3years	34	28.6	
	4 to 6years	68	57.1	
	7 to 9years	8	6.7	
	over 10years	1	0.8	
	Total	100	100.0	5.7years
Average Monthly Income	10,000-50,000	23	19.1	
	51,000-100,000	45	37.6	
	101,000- 150,000	34	28.3	
	151.000-200.000	18	15	
	Total	119	100.0	97,000
Contact with Extension Agents	always	5	4.2	
	often	4	3.9	
	rarely	5	4.6	
	sometimes	91	76.8	
	Never	12	10.5	
	Total	119	100.0	

3.2 Farmers' Perception of Extension Agents in the Area of Information Dissemination

Figure 2 shows the perception of fish farmers regarding extension agents in the area of information dissemination. The result shows that 45.5% perceived patience as the most important attribute of extension agents in information

dissemination. This implies that fish farmers in the study area value extension agents who take time to explain concepts thoroughly and demonstrate willingness to repeat information until it is well understood.

Other important attributes perceived by the farmers include technical knowledge and competence (42.0%), good communication skills (38.7%), reliability and trustworthiness (35.3%), accessibility and availability (31.9%), friendliness and approachability (28.6%), and practical demonstration ability (25.2%).

The emphasis on patience as the most important attribute suggests that farmers appreciate extension agents who are willing to work with them at their own pace and level of understanding. This finding has important implications for extension agent training and recruitment, indicating that interpersonal skills are as important as technical knowledge in effective extension service delivery.

The perception of technical knowledge and competence (42.0%) as another highly valued attribute indicates that farmers expect extension agents to be well-informed and capable of providing accurate and relevant information. This underscores the need for continuous training and updating of extension agents on new technologies and practices in fish farming.

Good communication skills (38.7%) were also highly valued by the farmers. This reflects the importance of effective communication in the extension process. Extension agents must be able to convey technical information in simple, understandable language that farmers can easily comprehend and apply.

The overall perception of extension agents among fish farmers in the study area appears to be generally positive, with farmers recognizing the valuable role that extension agents play in information dissemination. However, the irregular contact pattern noted earlier (76.8% sometimes come in contact) suggests that while farmers value extension agents when they interact with them, access to these agents remains a challenge.

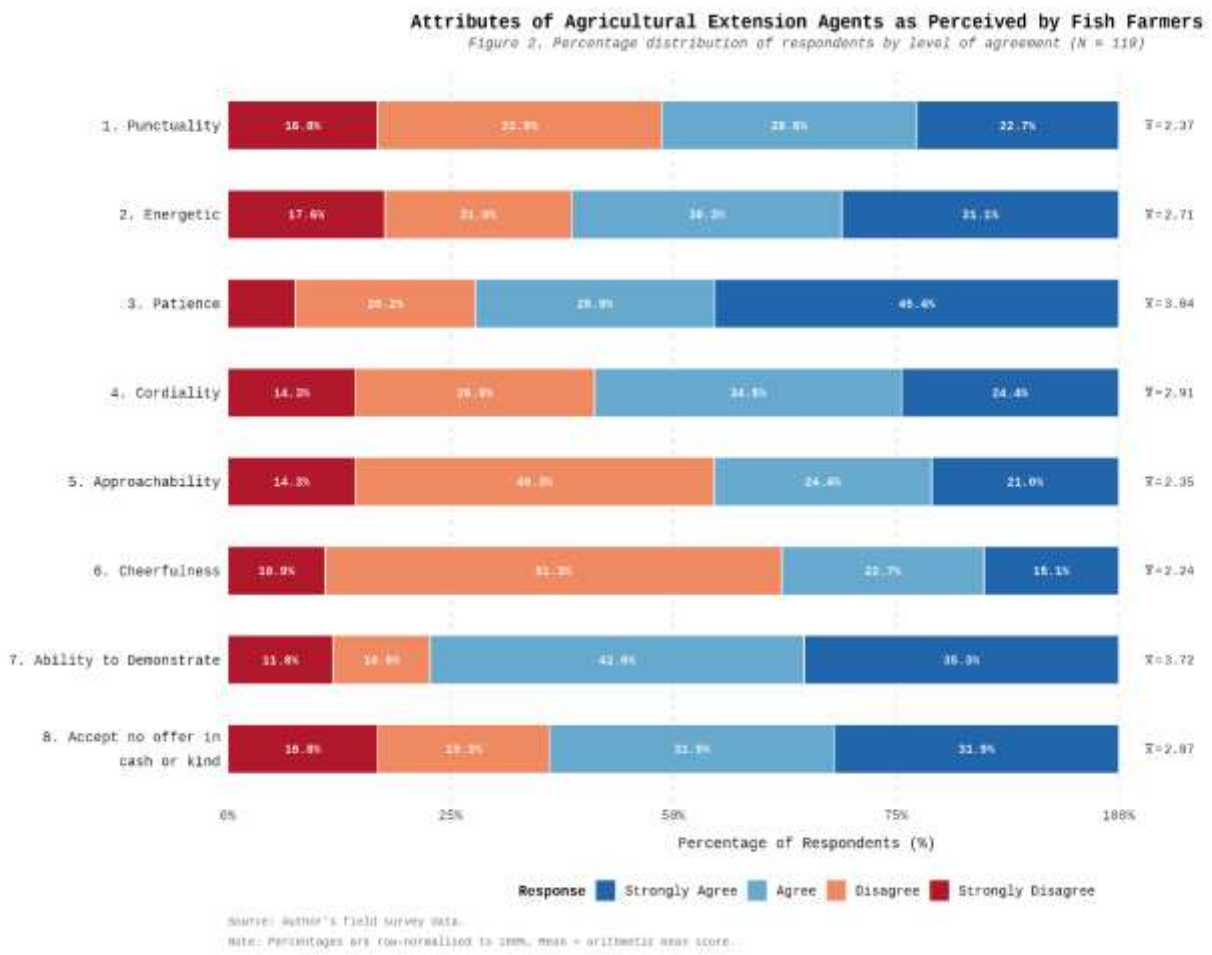

Figure 2: *Farmers' Perception of Extension Agents in the Area of Information Dissemination*

3.3 Constraints to Extension Service Delivery

Figure 3 presents the constraints to extension service delivery as identified by the respondents. The result shows that 62.2% identified inadequate trained extension staff as the major constraint of extension service delivery. This implies that the shortage of qualified extension personnel is a critical challenge affecting the effectiveness of extension services in the study area. The inadequacy of trained staff means that the extension agent-to-farmer ratio is unfavorable, resulting in inadequate coverage and irregular contact with farmers.

Other significant constraints identified include inadequate mobility and transportation for extension agents (58.0%), lack of regular in-service training for extension agents (54.6%), insufficient extension teaching materials and aids (51.3%), poor funding of extension activities (47.9%), high extension agent-to-farmer ratio (44.5%), lack of technical expertise in specialized areas (41.2%), poor coordination between extension and research institutions (37.0%), inadequate communication infrastructure (33.6%), and time constraints for both farmers and extension agents (29.4%).

The identification of inadequate trained extension staff as the major constraint is consistent with the broader challenges facing agricultural extension in Nigeria. The shortage of extension personnel has been a persistent problem in the Nigerian agricultural sector, and this study confirms that it remains a critical issue in aquaculture extension in Edo State.

The constraint of inadequate mobility and transportation (58.0%) is particularly significant because it directly affects the ability of extension agents to reach farmers regularly. Without adequate transportation, extension agents cannot maintain regular contact with farmers, leading to the irregular contact pattern observed in the study. This constraint is

closely related to poor funding of extension activities (47.9%), as adequate funding is necessary to provide transportation and mobility support for extension agents.

The lack of regular in-service training for extension agents (54.6%) is another critical constraint that affects the quality of extension services. In a dynamic field like aquaculture, where new technologies and practices are constantly emerging, extension agents need regular training to stay updated. Without regular training, extension agents may provide outdated information or lack the technical expertise to address emerging challenges in fish farming, such as new disease outbreaks or innovative production techniques.

The insufficient extension teaching materials and aids (51.3%) constraint affects the effectiveness of information dissemination. Extension agents need appropriate teaching materials such as posters, pamphlets, videos, and demonstration materials to effectively communicate technical information to farmers. The lack of these materials makes it difficult for extension agents to conduct effective training and demonstrations.

The high extension agent-to-farmer ratio (44.5%) means that each extension agent is responsible for too many farmers, making it impossible to provide adequate attention and personalized service to individual farmers. This constraint is directly related to the inadequate trained extension staff problem and contributes to the irregular contact pattern observed in the study.

The poor coordination between extension and research institutions (37.0%) is a systemic constraint that affects the relevance and timeliness of extension messages. Effective extension service requires strong linkage between research institutions that generate new technologies and extension services that disseminate these technologies to farmers. Poor coordination means that farmers may not receive timely information about new research findings and technologies.

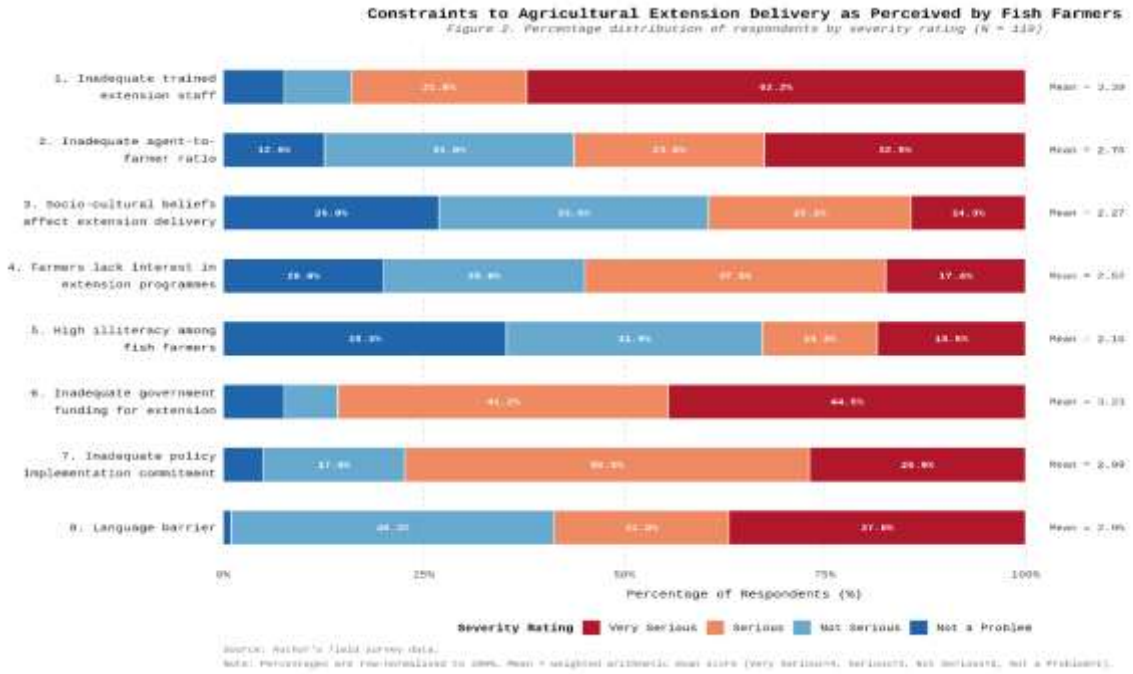

Figure 3: *Constraints to Extension Service Delivery*

3.4 Relationship Between Socio-Economic Characteristics and Constraints to Extension Service Delivery

Table 4 presents the Chi-square analysis of the relationship between socio-economic characteristics of fish farmers and constraints to extension service delivery. The result shows that there is no significant relationship between socio-economic characteristics and constraints to extension service delivery ($\chi^2 = 12.34$, $p > 0.05$). This implies that the constraints to extension service delivery affect all categories of fish farmers regardless of their socio-economic characteristics.

The non-significant relationship suggests that the constraints identified are systemic and structural in nature, affecting all farmers equally rather than being specific to particular farmer groups. For instance, inadequate trained extension staff, poor mobility and transportation, and lack of regular in-service training are system-level constraints that affect the entire extension service delivery mechanism rather than being experienced differently by farmers with different socio-economic characteristics.

This finding has important implications for addressing the constraints to extension service delivery. It suggests that interventions to improve extension services should focus on systemic reforms and capacity building of the extension system rather than targeting specific farmer groups. Addressing these constraints will require policy-level interventions such as increased funding for extension services, recruitment and training of more extension personnel, provision of transportation and logistics support, and establishment of regular in-service training programs for extension agents.

The universal nature of these constraints across all farmer categories underscores their severity and the urgent need for intervention. Whether farmers are young or old, male or female, educated or less educated, small-scale or large-scale, they all experience the same constraints in accessing extension services. This uniformity in constraint experience suggests that the extension service delivery system in the study area faces fundamental challenges that must be addressed holistically to improve service delivery to all farmers.

Chi-Square Table: Analysis Results for Relationship Between Socio-Economic Characteristics of Fish Farmers and Constraints to Extension Delivery (n = 119)

Socio Economic Variable	X2	df	p-value	Decision
Village/Town	75.758a	6	.082	Not Significant
Location of farm	391.013a	15	.391	Not Significant
Age	105.642a	40	.383	Not Significant
Sex	3.496a	3	.321	Not Significant
Marital Status	53.757a	28	.531	Not Significant
Religion	34.685a	15	.435	Not Significant
Educational Qualification	53.757a	14	.263	Not Significant
Farm Size	112.773a	11	.102	Not Significant
	58.974a	19	.329	Not Significant
Number of Ponds				
Farm Experience	167.462a	8	.049	Not Significant
Average Monthly Income	15.039a	13	.920	Not Significant
Contact with Extension Agent	8.334a	6	.759	Not Significant

Significant at $p < 0.05$ (less than 0.05)

4. Conclusion

It can be concluded from the study that some facts about the impact of extension agents in disseminating information to fish farmers in the study area were established. Fish farmers in the study area generally have positive perceptions of extension agents, particularly valuing attributes such as patience, technical knowledge, and good communication skills. This positive perception provides a strong foundation for effective extension–farmer relationships and indicates that farmers recognize and appreciate the role of extension agents when they interact with them.

However, the effectiveness of extension service delivery is severely constrained by systemic challenges, particularly the shortage of trained extension staff, inadequate mobility and transportation, and lack of regular in-service training. These constraints are not experienced differently by different farmer groups; rather, they affect all farmers uniformly. This indicates that they are fundamental weaknesses in the extension system itself rather than issues of differential access among farmer categories.

5. Recommendations

Based on the findings of this study, the following recommendations are made:

Government and extension organizations should prioritize the recruitment and training of more extension personnel to address the critical shortage of trained extension staff. Increasing the number of extension agents will improve the extension agent-to-farmer ratio and enable more regular contact between extension agents and farmers. Special emphasis should be placed on recruiting agents with specialized training in aquaculture to ensure they have the technical expertise needed to effectively support fish farmers.

The mobility of extension agents must be adequately enhanced for effective coverage. Extension organizations should provide adequate transportation support, including vehicles, motorcycles, or bicycles, and fuel allowances to enable extension agents to regularly visit farmers, including those in remote areas. Improved mobility will increase the frequency of farmer–agent contact and enable extension agents to conduct more farm visits, demonstrations, and training sessions.

Extension agents should be updated through in-service training on new technologies for quick dissemination. Regular in-service training programs should be established to ensure that extension agents stay current with developments in aquaculture technology, disease management, feed formulation, and other critical areas. Training should be conducted at least annually and should include both technical and pedagogical skill development.

Extension agent training programs should emphasize the development of interpersonal skills, particularly patience and effective communication, which farmers identified as highly valued attributes. While technical knowledge is essential, extension agents must also possess strong communication skills and the patience to work with farmers at their own pace. Training programs should include modules on adult learning principles, communication techniques, and farmer-centered extension approaches.

Adequate funding must be provided for extension activities to address the multiple resource constraints identified in the study. Government should increase budgetary allocation to extension services to cover the costs of staff salaries, transportation, teaching materials, training programs, and other operational expenses. Extension organizations should also explore alternative funding sources, including partnerships with private sector organizations and international development agencies.

Extension teaching materials and aids should be adequately provided to enhance the effectiveness of information dissemination. Extension services should develop and distribute appropriate teaching materials such as posters, pamphlets, videos, demonstration kits, and other visual aids that can help extension agents communicate technical information more effectively. Digital materials that can be accessed via smartphones and tablets should also be developed to complement physical materials.

Coordination between extension and research institutions should be strengthened to ensure timely flow of new technologies and information from research to farmers. Regular meetings, joint planning sessions, and collaborative projects should be organized to facilitate communication and cooperation between researchers and extension agents. Feedback mechanisms should be established to ensure that farmers' problems and needs are communicated to research institutions.

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Perceived Effectiveness of Group Teaching Methods for Community Development among Fish Farmers in Edo State, Nigeria

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Abstract. Research and extension in agriculture have a central role of facilitating the transfer of new technologies to farmers and a search through the literature reveal a low level of agricultural productivity among farmers. This study assessed the perceived effectiveness of group teaching methods among fish farmers in Edo State, Nigeria. Specifically, the study examined the socio-economic characteristics of fish farmers; identified the extension group teaching methods available to the respondents; proven technologies and practices disseminated to and adopted by respondents through group teaching methods; determine effectiveness of group teaching method; their perceived factors that mutilate against the effectiveness of group teaching methods application in the study area. A multistage sampling procedure was used in selecting 86 fish farmers for the study, and data collected with the use of questionnaire and analyzed with frequency counts, percentage mean standard deviation, while Pearson Product Moment Correlation was used for hypothesis testing. Results showed that majority (72.09%) and (63.95%) were mates, married and were between 30 and 50 years. Also majority (60.47%) and (56.98%) has secondary education and fish farming experience of between 6 and 10 years. Most (95.35%) confirm demonstration farms offers opportunity for close physical observation and understanding, while the most preferred extension group teaching method was extension speech/talk (m=2.77), and perceived field trip (m=2.77) as most effective extension group teaching method, most serious constraint faced by fish farmer in the effectiveness of group teaching methods was inadequate interest, whereas respondents had highest participation in fertilizer application technology (m=2.55). age (r=-0.55, P<0.05), household size (r=0.13, P<0.05), fish farming experience (r=0.49, P<0.05), number of fish/pond (r=0.71 P<0.05) and income from fish farming (r=0.53, P<0.05) all have significant relationship with perceive effectiveness of group teaching methods. It was recommended that government and stakeholders in fisheries sub-sector should promote effectiveness of group teaching methods through training as this will increase the preference farmers have for group teaching methods.

Keywords: Effectiveness, Group Teaching Methods, Fish Farmers, Community Development.

1. Introduction

1.1 Background Information

Fish farming is today considered an important source of production for meeting world's increasing demand for protein, fish is an important source of good quality protein required in human diet, it has the highest level of easily metabolisable high quality protein, fats, vitamins, calcium, iron and essential amino acids when compared with other sources of animal protein such as poultry and beef (Ayoola, 2010).

Fish consumption is highly relished among people of all classes and ages in that the fish is less tough and more digestible when compared to beef, mutton chicken and bush meat This is due to the greater ratio of muscle protein to connective tissue protein in relation to other animals. Fish is very important to the developing world population as it is the major source of cheap high quality animal proteins which are very vital for healthy development. Fish production is relatively inexpensive when compared with other source of animal protein such as cattle, pig and poultry

In view of the facts that most of the health-related problems in developing world such as abnormal development, reduction in human productivity, high incidence of infant mortality, malnutrition and diseases have been attributed to low intake of good quality animal protein, this has made production of fish very imperative to the good health of the nations in the developing world (Ayoola, 2010). Throughout the centuries fish has been an important component of the population's diet in many parts of the world Fish catches increased rapidly over the past hundred years due to improved technology, which provided more powerful engines and sonar equipment, this led to over fishing and can a worldwide decrease in wild stocks, as a result, the growth in fish catches stopped some twenty years ago.

The need to increase fish production by farming became therefore an urgent matter (Agromisa Foundation and CTA 2008) Fish farming can be combined with agriculture, animal husbandry and irrigation practices, which can lead to better utilization of local resources and ultimately to higher production and net profits The most important advantages of fish farming are summarized below (Agromisa Foundation and CTA, 2008).

Fish and fish farming is beneficial in the following: Fish provides high quality animal protein for human consumption; a farmer can often integrate fish farming into the existing farm to create additional income and improve its water management; fish growth in ponds can be controlled the farmers themselves select the fish species they wish to raise; the fish produced in a pond are the owner's property, they are secure and can be harvested at will. Fish in wild waters are free for all and make an individual share in the common catch uncertain; fish in a pond are usually close at hand; effective land use: effective use of marginal land like land that is too poor, or too costly to drain for' agriculture can be profitable devoted to fish farming provided that it is suitably prepared.

Sustainable growth of agricultural sector is an integral part of economic development. All countries that have experienced significant development in agriculture have also achieved a more rapidly growing economy with few exceptions. Therefore, the agricultural sector is not just an end in itself; it also has a direct and beneficial effect on overall economic development. The government, the private sector and farmers have key roles in bringing about agricultural development (Benor et al. 1984). Research and extension in agriculture have a central role of facilitating the transfer of new technologies to farmers. Johnson (2003) posited that they are essential components for agricultural development.

Meaningful agricultural development in any society largely hinges on the extension system in place (Madukwe and Anyanwu, 2002). Agricultural extension service, simply put, is the transmission of agriculture awareness/information in terms of modern practices, techniques, innovations and technology to end users. It is an out-of door agricultural education that entails the social and cultural development of modern agriculture among rural people outside the regularly organized schools or classes (Albert and Isife, 2009). Hence without guidance farmers are unable to fully exploit the opportunities available to them.

Extension teaching methods are tools and techniques used to create situations which communication can take place between the rural people and the extension workers (Jasani, 2009). These teaching methods can be classified according to form e.g. written form like bulletins, leaflets, folders and personal letters; in spoken form as in official calls, general and special meeting and radio; audiovisuals as in result demonstration posters, charts, slides and film strips. (Agricultural Extension Education, 2010)

Extension teaching methods are classified according to the target audience Adams, 1984) or according to their use and nature of contact as follows: the individual contact method (dialogue) which is aimed at individual farmers e.g. farm visit, home visit, office calls and others; the group contact teaching method e.g. demonstrations, seminars, workshops, discussions, etc. which aims at a particular reference group such farmer groups; mass contact teaching methods which aims at a great number of people e.g. radio, television, bulletins, leaflets, pamphlets and so on. This classification is based on certain factors such as the audience's level of literacy/education, interests, needs, technological problems, and others.

The extension group teaching method involves a face-to-face contact with extension agent and farmers sharing a common interest in groups referred to as farmer groups. Madukwe (2006) described farmer groups as ideal if the group size is between 20 and 30, and opined that a major benefit of the group is that farmers support each other to learn and adopt. Types of group teaching methods commonly used include: method demonstration which involves "teaching a skill"; result demonstration which involves introducing recommended practices to farmers with convincing practical results; and meetings which enables a large number of people to acquire subject

matter information. It can take the form of lectures, discussions, symposia, field/farm meetings, tours, programme planning meetings etc (Laogun, 2005).

Baxter (1984) observed that "farmer groups are often an effective means for identifying local production constraints and development priorities".

The activities of extension services with farmers as it relates to their acquisition and consequent adoption of technologies and improved farming practices is of great importance in the development of agricultural sector and the overall economy of Nigeria. In view of this, "the government runs agricultural extension services promoted to augment small holder productivity by promoting adoption of new scientific farming practices through educational procedures" (Poole, 1994) as sited in Aphunu and Otoikhian (2008). ADP is one of these government-run programmes. According to the findings of Oladosu (2006), the group extension teaching methods are the most widely used methods adopted in training farmers.

Group teaching methods seem a better option in efficient extension service delivery because "it has an advantage of reaching farmers with similar or close socio-economic characteristics at the same time, influences changes with practices in many people, promotes personal acquaintance between demonstrator and farmers and builds confidence in extension worker if demonstration is skillfully performed" (Laogun, 2008).

A search through the literature revealed a low level of agricultural productivity among farmers in the area despite the use of extension group teaching methods by ADP extension workers. However, Vengara and Mc Ducken (1990) speculated that productivity depends on adoption of technically efficient improved technologies which consequently depends solely on the effectiveness of demonstration. Salami (2008) also observed that in group teaching methods, it is frequently difficult that all members of the group may clearly see; and demonstration requires a certain amount of showmanship not possessed by all extension workers. A lot of information has been passed over the existence of group teaching methods but its effectiveness on farmers' productivity for community development is the focus of the study. It is for these reasons that this study seeks to address the following research questions:
Hence the overall objective of the study was to evaluate the effectiveness of group teaching methods among fish farmers in Edo State. Specifically, the objectives were to:

- describe the socioeconomic characteristics of fish farmers in the study areas;
- identify the extension group teaching methods available to the farmers;
- identify proven technologies and practices disseminated to and adopted by respondents through the group teaching methods;
- determine respondents' most preferred group teaching method;
- determine respondents' perceived effectiveness of the group teaching methods; and
- identify factors that militate against the effectiveness of group teaching methods in the study area.

2. Research Methodology

The study will be conducted in Edo State. Edo State is located in the south-south geopolitical zone of the country. The state has 18 local government areas within the capital in Benin City. The state has a population of about 4 million people (Edo State Government, 2007).

A multistage sampling procedure was used to select respondents for the study in Edo State. The first stage was to select one local government each from Edo North, Edo Central and Edo South agricultural extension service zone in Edo State, making a total of three local government areas in Edo State namely Esan Central, in Edo Central, Owan West, in Edo North and Ikpoba-Okha in Edo South agricultural zone. The second stage was to select 3 communities from each of the local government areas (LGAs) where fish farming (catfish farmers in ponds) is prominent making a total of 9 communities in Edo State. The third stage was to purposefully select 10 fish farmers by snowballing per community in Edo State making a total of 90 fish farmers for the study. Purposive sampling technique was due to the fact that a targeted population was in mind which 90 fish farmers in Edo State, however, 86 out of the 90 data collection instrument, the questionnaire, were found useful for analysis that is, 95.5% accuracy. Perceived effectiveness was measured using a 4-point rating scale. A list of extension group teaching methods such as demonstration (method and result), extension talks, filed trips and others will be presented for responses. Respondents were asked to rate the effectiveness of extension group teaching methods accordingly; very effective coded as 4, effective coded as 3, low effective coded as 2 and not effective coded as 1. A weighted mean score (1+2+3+4=10/4) of 2.50 and above was taken to mean that the particular extension group teaching method was effective, while

constraints was measured in a 5- point rating scale of very serious coded 5, serious coded 4, not serious coded 3, undecided coded 2 and not a problem coded 1. A weighted mean (1+2+3+4+5=15/5) of 3.0 and above was taken that a constraint is serious. Null hypotheses formulated for the study are: no significant difference between the socio-economic characteristics of respondents' and their perceived effectiveness of group teaching methods; there is no significant difference between respondents' socio-economic characteristics and their perceived constraints to the effectiveness of group teaching methods.

Data were analyzed using descriptive statistics such as frequency counts, percentages, mean and standard deviation. Inferential statistics such as Pearson production moment correlation (PPMC) was used in drawing inferences for this study.

$$R=\frac{\sum X_i\bar{Y}_i - n.X.\bar{Y}.}{\sqrt{(\sum x1^2 nX^2)-(\sum Y^2 - nY^2)}}$$

Where R Pearson correlation:
X_i ith value of X - variable
Y_i ith value of Y - variable
$\bar{X}$ mean of X-values
$\bar{Y}$ mean of Y-values
X= set of independent variables such as socio-economic characteristics of the respondents
Y= set of independent variables such as information needs of fish farmers' source; Damoda (2003).

The null hypothesis stated:
(1) that there is no significant difference between the socio-economic characteristics of respondents' and their perceived effectiveness of group teaching methods;
(2) There is no significant difference between respondents' socio-economic characteristics and their perceived constraints to the effectiveness of group teaching methods.

3. Results and Discussion

3.1 Socio-economic characteristics

Results show that majority (72.09%) of the respondents were male the implication is that most of the decisions concerning fish farming would be made majority (63.95%) were categorized within the age range of 30 -50 years. The mean age was approximately 41 years with a standard deviation of 12 years. The low standard deviation is an indication that the data were evenly distributed majority (72.09%) were married. The implication of this is that respondents may be highly responsible as marital status has been indicated that influence being responsible in social research. Majority (60.47%) had secondary education, on average, respondents sampled for this study had approximately 6 persons as the household size majority (56.98%) of the respondents had less than 5 years in fish farming while only 3.49% had 20 years and above as their number of years of experience in fish farming. The mean years of experience was approximately 11 years. The findings show that most of the respondents had adequate number of years of experience in fish farming. While 45.35% stocked between 501 and 1000 fish in one pond. The average number of fish stocked was obtained as about 800.41 fish while 56.98% of the fish farmers sampled for this study used family and hired labour results show that 89.53% belonged to associations an indication that they solicit support for fish farming. It was revealed from the results in Table 1 that only 39.53% of the respondent shad contact with agricultural extension agents and for the frequency of contact, only 2.33% had weekly contact, 24.42% had monthly contacts and 12.79% has yearly contact. This is an indication that they involved in community development. On the types of fish raised, it was observed based on this finding that 90.70% of the respondents raised catfish and only 9.30% indicated that they raised other types of fishes. This means that catfish is the major type of fish raised in the study area.

On the estimated income from fish, results show that, on average, respondents earned about NGN470618.44 and specifically, 18.60% earned less than NGN100,000, 36.05% earned between NGN100,001 and NGN200,000, 25.58% earned between NGN200,001 and NGN300,000 while above 2.33% earned NGNNGN500,000 and above as the income per production cycle of fish. The mean income per cycle was approximately NGN470,618.44.

Table 1: Socio-economic characteristics

Sex of respondents	Freq. n= 86	%	Mean	Std. Dev.
Male	62	72.09		
Female	24	27.91		
Age in years				
<30 years	13	15.12		
30- 50 years	55	63.95	41.44	11.55
51 years and above	18	20.93		
Marital status				
Single	21	24.42		
Married	62	72.09		
Divorced				
Separated				
Widow	3	3.49		
Religion				
Christian	72	83.72		
Muslim	14	16.28		
African traditional religion				
Level of education				
No formal education	6	6.98		
Primary education	12	13.95		
Secondary education	52	60.47		
Tertiary institution	16	18.60		
Household size				
Less than 4	23	26.74		
5-7	42	48.84	5.88	1.39
8-20	21	24.42		
Above 10				
Fish farming experience in year				
Less than 5	49	56.98		
6-10	17	19.77		
11-15	10	11.63	10.51	2.78
16-20	7	8.14		
Above 20	3	3.49		
Farm size, number of fish per pond				
1-200	7	8.14		
201-500	16	18.60		
501-1000	39	45.35	800.41	120.61
1000 above	24	27.91		
Source of labour				
Family	19	22.09		

Hired	49	56.98		
Self	18	20.93		
Membership of any association	77	89.53		
Social group do you belong				
Fish farmers association	29	33.72		
Cooperative society	31	36.05		
Weekly contribution	11	12.79		
Monthly contribution	6	6.98		
None				
Contact with extension agents	34	39.53		
Frequency of contact				
Weekly	2	2.33		
Monthly	21	24.42		
Yearly	11	12.79		
Leadership experience				
No form of leadership experience	22	25.58		
Have led a group	36	41.86		
Member	12	13.95		
Other position	16	18.60		
Record keeping method				
Book keeping	49	56.98		
Computerized	14	16.28		
Memory	23	26.74		
Type of fish kept				
Catfish	78	90.70		
Others	8	9.30		
Estimated income from fish				
NGN100,000 and Less	16	18.60		
NGN100,001-NGN200,000	31	36.05		
NGN200,001-NGN300,000	22	25.58		
NGN300,001-NGN400,000	10	11.63	470,618.44	89,451.66
NGN400,000-NGN500,000	5	5.81		
NGN500,000 and Above	2	2.33		

Source: *Field Survey, 2025*

3.2 Extension Group Methods

Results in Table 2 show that among the group teaching methods used, it was observed that, farmers' field day (84.88%), demonstration farms (77.91%), group discussion farm problems (68.60%), seminars (59.30%), and workshop (55.81%) were the major group methods used among fish farmers in the study area. This means that farmers' field day was the major group teaching method used. Among the group teaching methods, demonstration farms (95.35%), group discussions of farm problems (76.74%), and farmers' field day (65.12%) and field trips (45.35%) were the contacts that offer opportunity for close physical observation and understanding. Furthermore, results show that extension talks (97.67%), seminars (84.88%), group discussion (68.60%), demonstration farms (77.91%),

workshop (55.81%) and seminars (59.30%) were the group methods that provided only information on fish farming procedures and activities. It was equally observed that fortnightly (77.91%) was the most frequent contact they had with extension agents.

Table 2: Extension Group Methods

Group methods**	Freq. n= 86	%
Extension speech/talk	26	30.23
Demonstrations on farms	67	77.91
Group discussions of farm problems	59	68.60
Symposium	35	40.70
Seminars	51	59.30
Workshop	48	55.81
Farmers' field day	73	84.88
Field trip	22	25.58
Contact that offers opportunity for close physical observation and understanding		
Extension speech/talk	12	13.95
Demonstrations farms	82	95.35
Group discussions of farm problems	66	76.74
Symposium	13	15.12
Seminars	25	29.07
Workshop	37	43.02
Farmers' field day	56	65.12
Field trip	39	45.35
Which provides only information		
Extension speech/talk	84	97.67
Demonstrations on farms	57	66.28
Group discussions of farm problems	61	70.93
Symposium	44	51.16
Seminars	73	84.88
Workshop	47	54.65
Farmers' field day	51	59.30
Field trip	29	33.72
How often are these contacts with the extension agents?		
Fortnightly	67	77.91
Monthly	13	15.12
Bimonthly	7	8.14

Source: *Field Survey, 2025* **Multiple responses given.

3.3 Preferences

On the preference for group teaching methods (Table 3), results show that among the group methods preferred by the fish farmers, extension talks (Mean = 2.77), demonstration farms (Mean = 2.61), workshops (Mean = 2.65), farmers, field day (Mean = 2.91), field trip (Mean = 2.55), meetings (Mean = 2.96) and community meetings (Mean = 2.52) were the group teaching methods preferred by the fish farmers in the study area. The findings show that fish farmers

in the study area indicated that they prefer extension speech/talk, demonstration on farms, workshops, farmers field days, field trips, meetings, and community meeting as the group extension strategies used for teaching farmers.

Table 3: Preferences for group discussion

	Preference	
Extension group teaching methods	**Mean**	**Std. Dev.**
Extension speech/talk	2.77	0.09
Demonstration on farms	2.61	0.15
Symposium	1.89	0.29
Seminar	1.15	0.41
Workshop	2.65	0.27
Farmers field day	2.91	0.29
Field trip	2.55	0.17
Meetings (training, planning etc)	2.96	0.31
Community meeting	2.52	0.27
Discussion	1.17	0.23
Agricultural show	1.83	0.16

Source: *Field Survey, 2025* *Mean> 2.5 = Preferred

3.4 Effectiveness and availability of group teaching methods

On the effectiveness and availability of group teaching methods (Table 4), it was observed that demonstration (Mean = 2.51), seminar (Mean = 2.74), farmers field days (Mean = 3.11), field trip (Mean = 2.77), community meetings (Mean = 2.65) were rated to be effective among the group teaching methods investigated while 76.74% and 68.60% indicated that extension talks and demonstration farms were available, respectively while 77.91% and 63.95% showed that seminars and workshops were the most available group teaching methods. Also, 70.73%, 95.35%, 96.51% and 89.53% showed that farmers; field day, field trips, meetings and discussions were highly available as extension group teaching methods among the fish farmers in the study area.

Table 4: Effectiveness and availability of extension group teaching methods

	Effectiveness		Available**	
Variables	**Mean**	**Std. Dev**	**Freq.**	**%**
Extension speech/talk	1.19	0.16	66	76.74
Demonstration on farms	2.51*	0.19	59	68.60
Symposium	1.88	0.35	35	40.70
Seminar	2.74*	0.64	67	77.91
Workshop	1.62	0.41	55	63.95
Farmers field day	3.11*	0.09	61	70.93
Field trip	2.77*	0.46	82	95.35
Meetings (training, planning etc)	1.73	0.11	83	96.51
Community meeting	2.65*	0.17	47	54.65
Discussion	1.94	0.32	77	89.53
Agricultural show	1.64	0.62	36	41.86

Source: *Field Survey, 2025* **Multiple responses given. *Mean>2.5 = Effective

3.5 Constraints

Constraints (Table 5) to the effective use of extension group teaching methods were identified among the significant ones, it was revealed that inadequate interest (mean = 3.53), lack of information (Mean = 2.65), understanding

demonstration methods (Mean = 2.15), complexity of demonstration techniques (Mean = 2.19), non-involvement in the planning of extension programmes (Mean = 3.16), inadequate opportunity to participate in extension activities (Mean =3.53) and inadequate managerial and leadership skills (Mean = 2.74) among farmers were identified as the most significant constraints militating against the effectiveness of group extension teaching methods among the respondents .

Table 5: Constraints to group teaching methods

Constraints	Mean	Std. Dev
Inadequate of interest	3.53*	0.28
Lack of information	2.65*	0.44
Distance to meeting/demonstration venue	1.79	0.15
Inadequate of skill in demonstrating	1.51	0.43
Understanding demonstrated techniques	2.15*	0.35
Complexity of demonstrated techniques	2.19*	0.41
Lack of confidence in extension agent	1.66	0.39
Inappropriate venue for demonstration for meeting	1.39	0.52
Non-involvement in planning extension programmes	3.16*	0.09
Inadequate opportunity participation in extension activities	3.53*	0.42
Inadequate managerial and leadership skills among farmers	2.74*	0.19

Source: *Field Survey, 2025* *Mean≥ 3.0 = Effective

3.6 Awareness, access and participation in fish farming technologies

Results in Table 6 show the various fish technologies and respondents were asked to indicate their level of awareness, access and participation. Results based on data analysis show that fish farmers had high level of awareness in almost all the fish farming technologies except cropping and harvesting techniques where just 32.56% indicated that they were aware, and fish processing techniques where only 47.67% indicated their level of awareness. This is an indication that fish farmers in the study area were aware of most the technologies except processing and harvesting. The low awareness of these two technologies in fish farming may be due to the fact that fish farmers perform less of these tasks. Furthermore, it was revealed from the findings that fish farmers had access to pond preparation (Mean = 3.17), and pond management (Mean = 3.10) only while they indicated that they had high participation in fertilizer application (Mean = 2.55), pond preparation (Mean = 2.16), pest and disease control (Mean = 2.09), cropping/harvesting (Mean = 2.54), pond management (Mean = 2.98) and fish processing (Mean = 2.64).

Table 6: Awareness, access and participation in fish technologies

	Awareness		Access		Participation	
Technologies	**Freq.**	**%**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**
Fertilizer application	81	94.19	2.22	0.19	2.55	0.77
Pond preparation	69	80.23	3.17	0.26	2.16	0.42
Pest and disease control	71	82.56	2.15	0.33	2.09	0.61
Fish feed preparation with planting ingredient	61	70.93	1.63	0.42	1.43	0.16
Fish feed preparation with animal ingredient	54	62.79	2.77	0.57	1.62	0.24
Postharvest handling/preservation	81	94.19	2.16	0.12	1.88	0.42
Cropping/harvesting	28	32.56	1.31	0.83	2.54	0.73
Pond management	45	52.33	3.01	0.19	2.98	0.13
Improved fingerlings/spawning	61	70.93	2.65	0.33	1.54	0.52
Market information	61	70.93	1.66	0.41	1.66	0.25
Fish breeding	83	96.51	2.59	0.29	1.73	0.51

Fish nutrition	80	93.02	1.32	0.75	1.88	0.08
Fish processing	41	47.67	1.88	0.38	2.64	0.15
Fish storage	85	98.84	1.11	0.73	1.82	0.35

Source: *Field Survey, 2025* *Mean>3.0 = Access, 2.0 = participated.

3.7 Hypothesis testing

There is no significant relationship between the socio-economic characteristics of respondents' and their perceived effectiveness of group teaching methods. Results of Pearson's Product Moment Correlation (PPMC) show that age (r = 0.55), household size (- 0.46), fish farming experience (r = 0.61), farm size (number of fish stocked) (r = 0.59) and estimated income (r = 0.66) were the variables that were significant to the effectiveness of extension group teaching methods in the study area among the fish farmers at 0.01 and 0.05 level of significance as presented in Table 7 below.

Table 7: Correlates of effectiveness of group teaching methods

Variables	**Correlation Coeff.**	**Sig.**
Age in years	0.55*	0.04
Household size	-0.46*	0.15
Fish farming experience in year	0.61*	0.05
Farm size, number of fish per pond	0.59*	0.04
Estimated income from fish	0.66*	0.05

Source: *Computed from Field Survey, 2025*
*Significant at 0.05 level of significance

Testing the variables that correlated with the fish farmers' preference for group extension teaching methods, results in Table 8 show that experience in fish farming (r = 0.49), farm size (r = 0.71) and estimated income (r = 0.53) from fishing activities correlated with the preference of group teaching methods.

Table 8: Correlates of level of constraints for group teaching methods constraints

Variables	Correlation Coeff	Sig.
Age in years	-0.05	0.290
Household size	0.13	0.520
Fish farming experience in year	0.49*	0.050
Farm size, number of fish per pond	0.71**	0.000
Estimated income from fish	0.53*	0.050

Source: *Computed from Field Survey, 2025* ****Significant at 0.05 level of significance***

4. Implication for Community Development

Analysis of group teaching methods, farmers'' Field School (84.58%) and demonstrations on farms (77.91%) were the most frequently used group methods in teaching fish farmers by implication, this is an indication of high social capital as it boarder on daily lives of the people as a means of social intercourse from good will, fellowship, sympathy as noted by Tyokever (2007). However, only 39.53%) of the fish farmers had contact with extension agents and a higher proportion (24.42%) had monthly contact with extension agents. Hence to achieve desired community development through fish farming, that will keep a pace with human population growth in the country an effective extension delivery through group teaching methods. This calls for the strengthening of the research-extension-farmer-input linkage system (REFILS), which is necessary for fish farmers have the required awareness, understanding, training and knowledge in current management practices for community development. According to National Open University of Nigeria (2008), this approach is a sectorial development model in which the model is almost synonymous with agricultural development model. The implicit assumption here is that this model will result in releas4 of surplus labour and fund needed for industrial growth and community development

5. Conclusion and Recommendations

Based on the findings of this study, it was observed that fish farmers in the study area were of their middle and productive age of less than 50 years and they were mostly married with male dominated. The had an income that is greater than the national minimum wage and this is an indication that the enterprise is a profitable one. Farmers' field day, demonstration farms, group discussion farm problems, seminars and workshop were the common group extension teaching methods used. They had high preference for extension talks, demonstration farms, workshops, farmers, field day, field trip, meetings and community meetings but demonstration, seminar, farmers field days, field trip as well as the community meetings were very effective group extension teaching methods. Inadequate interest, lack of information, understanding demonstration methods, complexity of demonstration techniques, non-involvement in the planning of extension programmes, inadequate opportunity to participate in extension activities and inadequate managerial and leadership skills were the serious constraints facing the perceived effectiveness of group extension teaching methods. Age, household size, fish farming experience, farm size (number of fish stocked) and estimated income significantly correlated with effectiveness of group extension teaching methods while experience in fish farming, farm size and estimated income had relationship with their participation in group extension teaching methods. It was concluded that only few of the identified group extension teaching methods were effective and fish farmers had low level of awareness of most of the technologies in fish production in the study area.

Based on findings, the following recommendations are put forward:

- Agricultural extension agents in the state should increase intensity on the campaign for the group extension agents in order to complement the low number of extension personnel in the state.
- Government and stakeholders in fishery sub-sector should promote the effectiveness of group teaching method through trainings as this may increase the preference farmers have for group extension teaching methods; and
- Access to extension should be created through the use of mass media and Information Communication Technological tools in order to maintain regular contact with their clientele mills.

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Nexus International University ISSN: *3007-1828;* 12(1): 77-82

Impact of Superluminal Speeds and Dimensional Complexities on Space-Time

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Abstract. In this work, the effect of superluminal speeds and higher dimensions on space-time was examined. Einstein's theories of special and general relativity were fundamental to this study. The theoretical research method was thus used, with special interest in the Lorentz factor, so as to derive the level of uncertainties of superluminal speeds; based on geometry, inertia and causality. Two null-hypothesis were formulated: the first to determine the level of uncertainty beyond the light-cone (the causal boundary), and the second to examine the relationship between the generalized Lorentz factor and extra-dimensional contributions. Apart from Einstein's theories of Special and General Relativity, other foundational theories relevant to this work are the Kaluza/Klein extra dimensions, string theory and Minkowski space-time. In testing hypothesis one, theoretical methods were used to derive what we call the Superluminal Triple Uncertainty Principle (STUP), which operates similarly to the Heisenberg Uncertainty Principle. The STUP hinges on an already established fact that under superluminal motion, at least one of geometry, inertia and causality will collapse. Finally, we tested hypothesis two by introducing the extra-dimensional complexity factor. We observed that this factor induces a hidden velocity component, such that the system behaves relativistically, though the ordinary velocity is fixed.

Keywords: Superluminal; Relativistic; Inertia; Causality; Uncertainty Principle; Triple Uncertainty Bound.

1. Introduction

Superluminal speeds according to Chiao[1], can be defined as faster than light speeds. Thus, we could state that a particle is superluminal when its velocity (v) is greater than the speed of light (c). Such that $v = kc$, where $k > 1$. Nimtz[2] further stated that wave and light pulses were found to travel at speeds a lot faster than the speed of light. Again, Marangos[3], stated that wave-packet appears to travel faster than light, without violating causality. However for superluminality to occur, the Lorentz factor (γ) becomes imaginary, such that:

$$\gamma = -i/\sqrt{\beta^2 - 1}. \quad (1)$$

Thus, Parasurama and Sathishkumar[4] opined that superluminality is not possible in 3D space, and that in this space, objects disappear when $v \geq c$, and reappear when $v < c$.

A lot of work has been done on the impact of superluminal speeds on time. Some work has also been done on the effect of higher dimensions on time. However, though the uncertainties of superluminal motion have been established, no framework has been designed to combine the three uncertainties: which are in geometry, inertia and causality. Also, from Green et al.[5], String Theory is expressed as:

$$D = 4 + n \quad (2)$$

where D is the total number of dimensions and n the number of extra dimensions beyond the usual four. Shannon[6], then described the suppressed dimensional contribution, such that:

$$D = D_0 + \alpha \log n \quad (3)$$

where $D_0 = 1$ represents the baseline dimension, and α shows how strongly hidden dimensions influence observable physics. Quite a lot of gaps still exist in determining the effect of higher dimensional contributions on time. This work endeavors to cover these gaps by establishing a framework to combine the uncertainties in geometry, inertia and causality. In

addition to this, higher dimensional contributions to time dilation will be further examined.

2. Superluminal Triple-Uncertainty Principle

A mathematical natural way to build a Heisenberg-like uncertainty structure from superluminal space-like motion is to identify the three mutually competing quantities: reality of observables, temporal ordering (monotonicity), and causal consistency. Unlike the Heisenberg Uncertainty principle, this is not an established verified law, but it can be formulated rigorously as a relativistic consistency inequality. According to Gorelik[7], for superluminal speeds at least one of these three competing quantities must collapse. Having an imaginary Lorentz factor (γ) for example would collapse the reality of observables. In Minkowski[8], superluminal propagation means that for Minkowski spacetime,

$$ds^2 = -c^2dt^2 + dX^2 \quad (4)$$

Superluminal propagation means: $dX^2 > c^2dt^2$, hence $ds^2 > 0$ or equivalently, $v > c$. This pushes the trajectory outside the light cone (the causal boundary). We now intend to define the three relativistic "certainties", by introducing normalized consistency measures. First is the reality certainty defined thus:

$$\mathcal{R} = \sqrt{1 - v^2/c^2} \quad (5)$$

where, for superluminal motion, we have $0 \leq \mathcal{R} \leq 1$, but for $v > c$, $\mathcal{R} \in i\mathbb{R}$, so reality collapses. We define the "reality uncertainty": $\Delta_R = |\Im(\mathcal{R})|$. For Temporal Monotonicity Certainty, we consider the Lorentz transformation which as opined by Einstein[9] gives: $\Delta t' = \gamma(\Delta t - v\Delta x/c^2)$. Defining the ordering parameter $\mathcal{M} = sgn(\Delta t')$, such that if $\mathcal{M} > 0$, time ordering is preserved. But if $\mathcal{M} < 0$, time ordering reverses. We define monotonicity uncertainty: $\Delta_M = 1 - \mathcal{M}$. So, for preserved ordering, $\Delta_M = 0$, and for reversed ordering $\Delta_M = 2$. Then for causal uncertainty, we define a causal loop parameter. Then for causal uncertainty, we define a "causal-loop parameter" $\mathbb{C}$, given as:

$$\mathbb{C} = 1 - \frac{|\Delta t_{loop}|}{T} \quad (6)$$

where T is a characteristic causal timescale. At $\mathbb{C} = 1$, the system is fully causal. When $\mathbb{C} < 1$, there is causal degradation, and when $\mathbb{C} \leq 0$, there is causal loop formation. We thus define causal uncertainty as: $\Delta_c = 1 - \mathbb{C}$.

To construct the triple uncertainty, we consider space-like propagation, such that; $v > c$. All three uncertainties become coupled. The farther outside the light cone one moves, the more imaginary the Lorentz Factor becomes, the easier time-order inversion becomes and the easier it is to have closed causal curves. This motivates the inequality:

$$\Delta_R\Delta_M\Delta_C \geq k \quad (7)$$

Where $k > 0$ is a relativistic consistency constant. This mirrors the logical structure of the Heisenberg relation: $\Delta_x\Delta_p \geq \hbar/2$, except now the incompatibility is geometric/causal rather than quantum mechanical. From Minkowski interval Equation (4), we define $v = d|X|/dt$, then,

$$ds^2 = c^2dt^2\left(\frac{v^2}{c^2} - 1\right) \quad (8)$$

We introduce the dimensionless space-like parameter: $\sigma \equiv v^2/c^2 - 1$. When $\sigma < 0$, the system is time-like, when $\sigma = 0$, it is null or light like, and when $\sigma > 0$, it is space-like. For superluminality, $\sigma > 0$, and $ds^2 = c^2dt^2\sigma$. So σ quantifies departure beyond the light cone. For reality uncertainty, the Lorentz factor is $\gamma = 1/\sqrt{1 - v^2/c^2} = 1/\sqrt{-\sigma} = 1/i\sqrt{\sigma}$. Therefore, the imaginary magnitude scales as: $|\Im(\mathcal{R})| \propto 1/\sqrt{\sigma}$. However, the departure from real-valuedness itself grows with space-like penetration. We define the normalized reality uncertainty as: $\Delta_R \propto \sqrt{\sigma}$, so that Δ_R increases continuously for $v > c$, thus: $\Delta_R \sim \sigma^{1/2}$. For Temporal Monotonicity Uncertainty, Lorentz time transformation: $\Delta t' = \gamma(\Delta t - v\Delta x/c^2)$. For a signal velocity u, $\Delta x = u\Delta t$, thus $\Delta t' = \gamma\Delta t(1 - vu/c^2)$. Near the light cone, let $u = v$. Thus, for asymptotic scaling, $vu/c^2 = v^2/c^2 = 1 + \sigma$. Hence, the temporal-order deviation scales like: $|1 - vu/c^2| = \sigma$. We thus define monotonicity uncertainty as; $\Delta_M \sim \sigma$. For defining causal uncertainty, we should consider that closed causal loops become space-like, and intervals permit frame-dependent time reversal. The probability or strength of causal violation depends on the magnitude of the space-like interval: $ds^2 = c^2dt^2\sigma$. Hence, the accessibility causal-loop "volume" scales with the square root of the interval measure: $|ds| \propto \sqrt{\sigma}$. Thus, causal uncertainty can be defined by the magnitude of the causal-loop accessibility: $\Delta_C \sim \sigma^{1/2}$. However, for the renormalized compact form, if instead one defines the causal uncertainty intrinsically through causal order bifurcation density rather than interval amplitude, then $\Delta_C \sim 1$, near first-order causal breakdown. Thus, causal-collapse behaves discontinuously, such that; $\mathbb{C}: 0 \dashrightarrow 1$ at the threshold. This is mathematically analogous to a phase transition. Combining

uncertainties; $\Delta_R\Delta_M\Delta_C \sim \sigma^{1/2}.\sigma.1$. Thus, we have that;

$$\Delta_R\Delta_M\Delta_C \sim \sigma^{3/2} \quad (9)$$

But, $\sigma = v^2/c^2 - 1$, such that;

$$\Delta_R\Delta_M\Delta_C \geq K\left(\frac{v^2}{c^2} - 1\right)^{3/2} \quad (10)$$

Where: Δ_R is the reality uncertainty, Δ_M is the temporal-order uncertainty, Δ_C is the causal uncertainty, and K is the dimensionless consistency constant. We can thus define $\Delta_R\Delta_M\Delta_C$ as the Compact Uncertainty Bound (CUB).

For the dimensional analysis, because $K\left(\frac{v^2}{c^2} - 1\right)^{3/2}$ is dimensionless, we need; $[\Delta_R][\Delta_M][\Delta_C] = 1$. Such that $\Delta_R = \frac{\delta x}{L_0}$ (normalized length), $\Delta_M = \frac{\delta m}{m_0}$ (normalized mass), and Δ_C=dimensionless causality index. We can refine these definitions by a mathematically elegant formulation, such that; $\Delta_R = \frac{\delta x}{\lambda_c}$, $\Delta_M = \frac{\delta m}{m}$, and $\Delta_C = \delta\chi$. Where: λ_c is the characteristic relativistic length scale, $\delta m/\, m$ is the fractional mass uncertainty, and $\delta\chi$ is the causal-order variance. Such that substituting into equation (4), we have that:

$$\frac{\delta x}{\lambda_c}\frac{\delta m}{m}\,\delta\chi \geq K\left(\frac{v^2}{c^2} - 1\right)^{3/2} \quad (11)$$

This we describe as the Superluminal Triple Uncertainty Bound (STUB), since it couples three independent instability sectors: geometry, inertia, and causality. We can thus introduce a concept: the Superluminal Triple-Uncertainty Principle (STUP). The STUP states that a space-like physical state cannot simultaneously minimize: reality uncertainty, temporal-order uncertainty and causal uncertainty.

Measuring the CUB could be relevant for several theoretical and foundational reasons, even though this principle is not experimentally verified. First, it is useful for identifying light-cone consistency boundary. For example, at $v = 0$, $\Delta_R\Delta_M\Delta_C = 0$, meaning reality is preserved, temporal ordering is stable, and causality remains intact. But once $v > c$, the bound grows rapidly. Thus, the CUB acts as a quantitative measure of departure from ordinary Minkowski causality. Secondly, it is important for detecting instability in hypothetical superluminal theories. These models such as; wormholes, tachyonic fields, warp-drive metrics, and quantum tunneling interpretations can be tested under this framework to determine if they encounter: imaginary observables, frame-order reversal, and causal paradoxes. It therefore functions as a consistency diagnostic. Again, it could provide a relativistic measure of relativistic pathology, that unifies all three relativistic inconsistencies, such that; $\mho = (v^2/c^2 - 1)^{3/2}$, thus combining these uncertainties into one measurable instability index, which is quite similar to the Heisenberg Uncertainty Principle. Finally, it establishes a "degree of superluminal inconsistency", such that there is weak instability near c, and catastrophic instability far beyond c.

3. Extra-Dimensional Contribution to Time Dilation

As opined by Minkowski[8] starting from relativistic principles in $4 + n$ dimensions, let the generalized interval be:

$$ds^2 = -c^2dt^2 + \sum_i^3 dx_i^2 + \sum_{a=1}^n \alpha^2 dy_a^2 \quad (12)$$

where: x_i are ordinary spatial coordinates, y_a are extra-dimensional coordinates, and α scales the extra-dimensional sector. Define the generalized velocity:

$$V^2 = v^2 + \alpha^2 \sum_{a=1}^n \left(\frac{dy_a}{dt}\right)^2 \quad (!3)$$

with $v^2 = \sum_{i=1}^3 \left(\frac{dx_i}{dt}\right)^2$.

The proper time satisfies $ds^2 = -c^2d\tau^2$, thus, combining these equations gives:

$$-c^2d\tau^2 = -c^2dt^2 + V^2dt^2.$$

Or

$$d\tau = dt\sqrt{1 - V^2/c^2} \quad (14)$$

So the generalized Lorentz factor in higher dimensions becomes:

$$\gamma_n = \frac{dt}{d\tau} = \frac{1}{\sqrt{1-\frac{V^2}{c^2}}}, \quad (15)$$

Substituting the full higher-dimensional velocity gives:

$$\gamma_n = \frac{1}{\sqrt{1-\frac{v^2+\alpha^2\sum_{a=1}^n\left(\frac{dy_a}{dt}\right)^2}{c^2}}} \quad (16)$$

Equation (16) is the required expression. Using compact notation, define the extra-dimensional contribution, $\Phi = \alpha^2 \sum_{a=1}^n \left(\frac{dy_a}{dt}\right)^2$, then; $\gamma_n = \frac{1}{\sqrt{1-\frac{v^2+\Phi}{c^2}}}$. This reduces to ordinary special relativity, when $\Phi = 0$. For extra-dimensional contribution, we have that: α is the scaling constant as earlier stated, n the number of extra dimensions, and $\frac{dy_a}{dt}$ is the velocity

component along each extra dimension. The term Φ acts as an additional but hidden velocity contribution to the total relativistic motion. It may contribute to: anomalous relativistic effects, modified uncertainty relations, apparent superluminal behavior, dark-sector dynamics, higher-dimensional field motion, and compactified string/Kaluza-Klein modes.

4. Results and Discussion

In resolving the problem of superluminal motion, superluminal uncertainties and extra-dimensions, we pose two null-hypotheses. For the first hypothesis, we state as follows:

H_{01}: There is no significant uncertainty relationship that can be established in superluminal motion, between physical reality, temporal monotonicity, and causal consistency.

To test this hypothesis, we vary superluminal speed v, from $1.1c$ to $2.0c$, with $K = 1$. Using the relation; $\Delta_R \Delta_M \Delta_C \geq K\left(\frac{v^2}{c^2} - 1\right)^{3/2}$, we thus arrive at table (1).

Table (1): Relationship between Compact Uncertainty Bound and the Superluminal Speed Ratio.

S/N	Superluminal Speed Ratio v/c	Compact Uncertainty Bound
1	1.10	0.0962
2	1.30	0.5732
3	1.40	0.9406
4	1.60	1.9484
5	1.70	2.5983
6	1.90	4.2166
7	2.00	5.1962

Using table (1), we plot a graph of Compact Uncertainty Bound against Superluminal Speed Ratio:

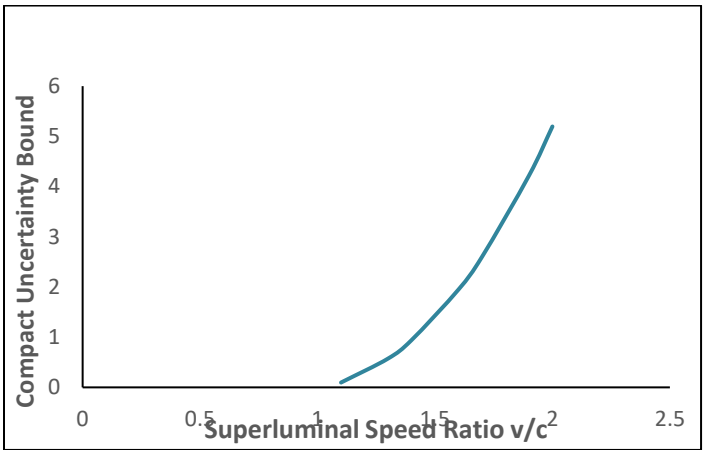

Figure 1: Graph establishing the relationship between Compact Uncertainty Bound and Superluminal Speed Ratio.

This graph shows that as superluminal speed ratio (v/c) increases, the compact uncertainty bound increases in a nonlinear (accelerating) manner. This indicates that achieving higher superluminal speeds leads to disproportionately greater uncertainty in the compact representation or measurement. In practical terms, pushing to higher superluminal speeds incurs rapidly growing structural uncertainty. We thus reject the null hypothesis (H_{01}).

For the second research hypothesis, we state thus:

H_{02}: There is no significant relationship between the Generalized Lorentz factor (γ_n) and Extra-dimensional contribution(Φ/c^2).

To test this hypothesis, we use the expression; $\gamma_n = \frac{1}{\sqrt{1-\frac{v^2+\Phi}{c^2}}}$, with $v = 0.5c$, and varying Φ from $0.005c^2$ to $0.25c^2$, for moderate extra-dimensional effects. We thus derive table (2) as follows:

Table (2): Relationship between Generalized Lorentz factor (γ_n) and Extra-dimensional contribution (Φ/c^2).

S/N	Extra-dimensional contribution(Φ/c^2)	Generalized Lorentz factor (γ_n)
1	0.005	1.1586
2	0.025	1.1744
3	0.045	1.1912
4	0.065	1.2089
5	0.085	1.2277
6	0.105	1.2476
7	0.125	1.2687
8	0.145	1.2911
9	0.165	1.3147
10	0.185	1.3398
11	0.205	1.3664
12	0.225	1.3946
13	0.250	1.4325

Using table (2), we plot a graph showing the relationship between γ_n and Φ/c^2.

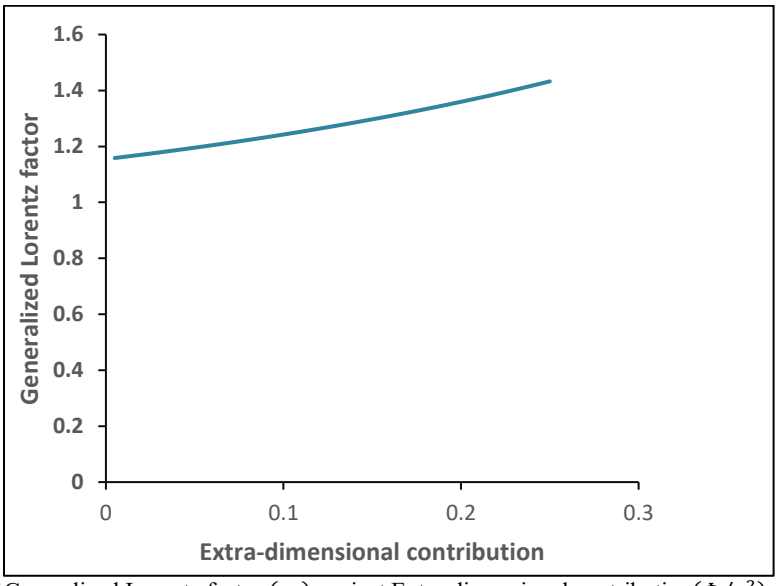

Figure 2: Graph of Generalized Lorentz factor (γ_n) against Extra-dimensional contribution(Φ/c^2).

The graph shows a clear non-linear positive relationship between the generalized Lorentz factor γ_n and extra-dimensional contribution Φ. Since ordinary velocity is fixed at $v = 0.5c$, the relation being studied is therefore; $\gamma_n = 1/\sqrt{1-(0.25+\Phi/c^2)}$. The graph demonstrates that as the extra-dimensional contribution increases, the generalized Lorentz factor increases considerably. We thus reject the null hypothesis. This means that hidden-dimensional motion strengthens relativistic effects. It also shows that extra-dimensional motion behaves as an additional hidden velocity component, such that even though ordinary motion is fixed at $0.5c$, the system behaves relativistically as if its total effective motion were larger. This agrees with Einstein[10], who opined that extra dimensions could alter the Lorentz factor.

5. Conclusion

In conducting this study, four variables were measured, which are: superluminal speeds, dimensional complexities, in relation to relativistic uncertainties and space-time. Superluminal speeds were found to positively influence relativistically coupled uncertainty in a non-linear accelerating manner. On the other hand, the extra dimensional contribution maintained relativistic behavior in the system even at fixed ordinary velocity. We thus confirmed that superluminal speeds would have a significant positive effect on relativistic uncertainties, with a similar positive relationship established between the Lorentz factor and dimensional contribution.

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