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Volume 1 (2024)

PROCEEDINGS OF THE 5TH ANNUAL CIRCULARITY AFRICA CONFERENCE 2024

Edited by
Olawale Emmanuel Olayide
Olusola Abiola Ladokun

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of the
5th Annual Circularity Africa Conference 2024

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Theme:
Achieving Environmentally Sound Management of Chemicals and Wastes in Africa

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PREFACE

The Annual Circularity Africa Conference organised by the Africa Circular Economy Research and Policy Network (ACERPiN) has become the confluence of research, policy and practice on circular economy in Africa. The fifth edition of the conference was organised in collaboration with the Lead City University, Ibadan, Nigeria. The conference was held at the Lead City University, Ibadan during 8 - 10 May, 2024. The conference had over 350 participants in attendance with over 85 technical and policy paper presentations. In addition, the conference featured four keynote addresses delivered by Professor Bamidele Olu-Owolabi, University of Ibadan, Nigeria; Dr Desalegn Ayal, Addis Ababa University, Ethiopia; Dr Kaustubh Thapa, Radboud University in the Netherlands; and Mrs Amina Imam-Binuyo, Federal Ministry of Water Resources and Sanitation, Nigeria.

The theme of the conference was ***Achieving Environmentally Sound Management of Chemicals and Wastes in Africa.*** The selected technical papers covered the theme and sub-themes of the conference.

a) International multilateral agreements on hazardous waste and other chemicals
b) Air, water and soil pollution
a) Food, nutrition and biofortification
b) Chemical pollution and bioremediation
c) Desertification and climate change
d) Food safety and health
e) Regenerative agriculture
f) Plastic waste
g) Electronic waste
h) Biodiversity management
i) Chemical management and ecocide
j) Carbon footprints, carbon offset and deep decarbonisation
k) Petrochemicals and divestment
l) Industrial ecology and eco-industrial parks
m) Chemical trade and ultimate producer responsibility
n) Oceans and blue economy
o) Renewable energy and green growth

I hereby present to you the First Volume of **Circularity: Proceedings of the Annual Circularity Africa Conference (2024).** This is the registered name and identity of the compendium of papers (with International Standard Book Number, ISBN) of the annual Circularity Africa Conference organised by the Africa Circular Economy Research and Policy Network (ACERPiN), and facilitated by the Interconnections for Making Africa Great Empowered and Sustainable (IMAGES) Initiative.

Thank you.

Dr Olawale Emmanuel Olayide
President, Africa Circular Economy Research and Policy Network & IMAGES Initiative

CHEMICALS: BLESSINGS AND CURSES

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ABSTRACT

Chemicals are everywhere. We are actually living in a world of chemicals. Chemicals play crucial roles in our lives. It transforms industries and boosts humans' quality of life. Virtually all manufactured goods contain chemicals, with chemicals being key components of plastics, textiles, cosmetics, cleaning products, paints, glues and a broad range of other consumer products. Therefore, the chemical sector plays a key role in improving quality of life.These chemicals have dual nature: Blessings and Curses. Some are fairly safe while others should be handled with care because of the significant risks and challenges they pose to our health and the environment. This presentation will look at the positive and negative impacts of chemicals, regulations and safety measures, management of chemicals for sustainable development. Chemicals are essential part of our economy and can improve life, health and wellbeing of people across the nation. Chemicals like sulphuric acid, methyl chloride, toluene and benzene are critical solvents used in manufacturing and processing of items that are needed in day to day life. However, the handling, transportation, storage, usage and disposal of chemicals at facilities and workplaces can present safety and security risks that can endanger human life.

INTRODUCTION TO CHEMICALS AND ENVIRONMENT

Chemicals are pervasive in the environment. Chemicals play a significant role in modern society, with widespread applications across various industries. Many chemicals and chemical products are essential to modern life because of the benefits they provide. Some break down quickly, while others persist for long periods in the environment and may bioaccumulate in the food chain (e.g., persistent, bioaccumulative, and toxic chemicals). Since 1950, chemical production has increased fiftyfold, and it is projected to triple by 2050. It has been estimated that approximately one thousand new chemicals come into the market every year, These chemicals are usually found as mixtures in commercial products. At the global level, there are an estimated 350,000 chemicals on the market (Wang et al., 2020). Of the 350,000 chemicals in use, only a small number have been fully assessed for safety.

One to two million of such products or trade names exist in most industrialized countries. However, the impact of chemical usage on the environment is an area of growing concern. The increase in the production of chemicals has resulted into more storage, transport, handling, use and disposal of chemicals problems. Thus, the whole life cycle of chemicals must be considered when assessing their benefits and havocs (Wang et al., 2020).

What are chemicals? Chemicals are substances with a distinct molecular composition. They play a crucial role in our daily lives, from the water we drink to the air we breathe. They can exist in various states - solids, liquids, or gases - and can undergo chemical reactions that transform them into new substances.

Environmental chemicals refer to chemical compounds or elements present in air, water, food, soil, dust, or consumer products. They can be naturally occurring or human-made and may have various health effects. For example, Chemicals are introduced into the environment through acts of nature (e.g., volcanoes, hurricanes, examples are oxides of sulphur and carbon, hydrogen fluoride, sulphide and chloride) and chemicals are used to make products such as cosmetics, plastics, cleaning supplies, and electronics. Some common environmental chemicals include arsenic, cadmium, lead, mercury, polybrominated diphenyl ethers (PBDEs), polycyclic aromatic hydrocarbons (PAHs), and volatile organic compounds (VOCs) (https://www.who.int/ipcs/assessment/public_health/chemicals_phc/en/).

Most chemical accidents have a limited effect. Occasionally there is a disaster like the one in Bhopal, India, in 1984, with thousands of deaths and many people permanently disabled. It is not just the worker handling chemicals who is at risk. We may be exposed in our homes through misuse or by accidents, and be contaminated by consumer products including food. The environment may be affected by chemicals through pollution of the air we breathe, the water we drink, and the food we eat. They may have entered into forests and lakes, destroying wildlife and changing the ecosystems. Chemicals are not all of equal concern. The assessment of health risks of chemical substances is a continuous process where information of the chemical hazards is made available through a variety of sources (Persson et al. 2022; Shetty et al., 2023)

CHEMICALS AS BLESSINGS

Improved Quality of Life: Chemicals have enabled the development of modern medicines, electronic devices, and materials that enhance our lives. From cleaning products to technological innovations, chemicals have created safer and more convenient consumers goods.

Increased Industrial Productivity Efficiency: Chemicals have played a crucial role in industrialization and global trade, leading to increased efficiency and economic growth. Chemical processes and products enhance efficiency in various sectors, such as agriculture, manufacturing, and transportation.

Advancements in Medicine: Chemicals have revolutionized healthcare, enabling the development of life-saving drugs and treatments. The pharmaceutical industry relies on chemicals to create life-saving medications and treatments for countless diseases.

Enhancing Agricultural Productivity and Sustainable Agriculture: Through fertilizers and pesticides, chemicals have boosted crop yields, ensuring adequate food supply. Chemical innovations support eco-friendly farming practices, fostering sustainable food production.

Science and Technology Advancements: Chemicals have enabled scientists to conduct research and develop new technologies that have transformed our understanding of the world and our ability to manipulate it. Chemicals are innovation catalysts. Chemicals drive innovation by enabling the development of new materials, fuels, and technologies that improve our lives.

Clean Energy: Chemistry enables breakthroughs in renewable energy sources, such as solar panels, reducing our reliance on fossil fuels (Funk and Ash, 2020, Abdul Mojeed, 2018, Kulkarni, S. 2022).

CHEMICALS AS CURSES

Everything has two faces – either good or bad. In the world of spirituality, they're called angel and evil, while they are known as positive and negative powers, respectively, in Chemistry. Chemical is synonymous to Chapter 28 of Deuteronomy where verses1-14 are BLESSINGS and from verse 16-68 the CURSES. In verse 15:

BUT IF YOU WILL NOT OBEY THE VOICE OF THE LORD YOUR GOD BEING WATCHFUL TO DO ALL HIS COMMANDMENT AND HIS STATUES WHICH I COMMAND YOU THIS DAY, THEN ALL THESE CURSES SHALL COME UPON YOU AND OVERTAKE YOU.

THIS CAN BE RECASTED AS:
"IF THESE CHEMICALS ARE NOT PROPERLY USED; THEY WILL ENDANGER OUR LIVES AND INFLICT HAVOCS TO THE ENVIRONMENT"

The harmful effects of chemical substances depend on the toxicity and the exposure to that chemical. Toxicity is a property of the chemical substance, while the exposure depends on the way the chemical is used. The level of exposure depends on the concentration of the hazardous chemical and on the period of contact time. Many substances do not give any warning by odour, even though they may be present at dangerous concentrations in the workplace air.

The following are some of the havocs inflicted on the environment and humans by chemicals:

Environmental Pollution: Chemical pollutants can harm ecosystems, contribute to climate change, and endanger wildlife. Chemicals contribute to air, water, and soil pollution, posing serious risks to human health and ecosystems (Wang et al., 2020).

Health Risks: Exposure to certain chemicals can lead to various health issues, including allergies and respiratory problems. Improper handling or exposure to hazardous chemicals can lead to severe health issues and long-term consequences. The recently published EEA zero pollution monitoring assessment (EEA, 2022a) highlights the key ways in which chemicals impact ecosystems and human health. For instance, the assessment shows that people's health is being adversely affected by hazardous chemicals that pollute our bodies. Children are particularly vulnerable to the effects of chemicals. There are also positive developments; Europe has been maintaining and improving its bathing and drinking water quality and reducing the risk of antimicrobial resistance. Encouraging trends are taking place in reducing pesticide use, although any resulting positive impact on the environment is yet to be seen (https://www.eea.europa.eu/publications/managing-the-systemic-use of chemicals in Europe).

Environmental Degradation: Excessive use of certain chemicals can disrupt ecosystems, endangering endangered species and causing ecological imbalances. Chemical pollution degrades ecosystems, reduces biodiversity and affects the ecosystem services that provide clean drinking water and enable food production. Pollution is of particular concern when hazardous substances are persistent, bioaccumulative and mobile — leading to their widespread distribution in environmental media and their bioaccumulation in living organisms (Naidu et al, 2023)

In order to avert all these curses, there must be regulations/control guiding the production and use of these chemicals.

WAY FORWARD: ROLE OF SCIENTISTS

Understanding Chemical Interactions: Intensive research to unravels complex chemical reactions, provides insights for future applications, discover new chemicals that are safer, more effective and have minimal negative environmental impact.

Green Chemistry: Developing sustainable alternatives to harmful chemicals/processes.

Circular Economy: Promoting eco-friendly practices and recycling of wastes.

CONCLUSION

While chemicals have undeniably transformed our world, we must tread cautiously. With responsible practices, advancements in technology, and strong regulations, we can harness the benefits of chemicals while minimizing their adverse effects. It is our collective responsibility to ensure a safer, healthier, and sustainable future.

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REDEFINING FASHION: EMBRACING TRADITION AND SUSTAINABILITY IN CLOTHING DESIGN

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ABSTRACT

Fashion is currently undergoing a significant transformation towards sustainability, as there is an increasing recognition of the importance of incorporating tradition and heritage into clothing design. Despite the thriving traditional craftsmanship in many communities, the emergence of fast fashion has introduced new complexities to the industry. The influx of cheaply manufactured clothing imports has placed local artisans and manufacturers at a disadvantage, leading to economic disparities and a loss of cultural identity. This study delves into the convergence of tradition, sustainability, and functionality within the modern fashion landscape. It explores innovative approaches to integrating traditional textiles, such as Aso Oke and Adire, into clothing design while advocating for upcycling initiatives to minimize waste and safeguard cultural heritage. By breathing new life into these revered textiles, individuals can simultaneously reduce waste and promote sustainability. Furthermore, the study addresses various structural enhancements that can be implemented to augment the functionality and allure of upcycled garments. It proposes methods for revitalizing local clothing ideas to align with contemporary trends, ensuring functional and stylish apparel that resonates with current fashion preferences. Through an extensive exploration of design innovations, educational initiatives, and advocacy efforts, this presentation underscores the potential for fashion to serve as a catalyst for social and environmental transformation. By creating functional and stylish apparel that preserves cultural heritage, the fashion industry can pave the way towards a more equitable and resilient future. By mobilizing government support, leveraging the influence of celebrities and influential figures, and fostering collaboration across sectors, we can foster the widespread acceptance of sustainable clothing, traditional attire, and upcycling initiatives. This collective effort ensures a more sustainable and culturally rich fashion landscape for future generations. In conclusion, by nurturing a culture of sustainability, preserving traditional craftsmanship, and embracing innovative solutions, Africa can harness its rich artistic heritage to build a more resilient and environmentally conscious clothing industry for the future.

Key words: *Fast fashion, Sustainability, Functionality, Aso-oke, Tie-dye*

INTRODUCTION

Africa, with its vibrant cultural diversity and rich artistic heritage, has long been celebrated for its unique clothing traditions (Rabine, 2002). While traditional craftsmanship continues to thrive in many communities, the rise of fast fashion has introduced new dynamics to the industry (Brooks, 2015). With the influx of cheaply manufactured clothing imports, local artisans and manufacturers often struggle to compete, leading to economic disparities and loss of cultural identity (Fletcher, 2013).

The proliferation of fast fashion has exacerbated Africa's clothing disposal problem, leading to an alarming rate of clothes waste (Bukhari et al., 2018). Many consumers influenced by trends and advertising, discard garments after only a few wears, contributing to a culture of disposability (Morgan & Birtwistle, 2009). In urban centers, overflowing landfills and informal dumping sites bear witness to the unsustainable consumption patterns prevalent in the region (Abimbola, 2012; Piippo & Niinimäki, 2021).

The disposal of clothing poses significant environmental threats to Africa's delicate ecosystems. Synthetic fabrics, commonly used in fast fashion, take hundreds of years to decompose, releasing harmful microplastics into the soil and waterways (Henry et al., 2019; Napper & Thompson, 2016). Landfills filled with discarded textiles emit greenhouse gases, contributing to climate change and air pollution. Moreover, the chemical dyes and finishes used in garment production can contaminate soil and groundwater, posing risks to human health and biodiversity (Kant, 2012).

Restoration in Clothing

The fashion industry is notorious for its high levels of waste, with millions of tons of clothing ending up in landfills each year (Ellen MacArthur Foundation, 2017). Restoration offers a solution to this problem by diverting garments from the waste stream and giving them a new lease on life through repair, alteration, or upcycling, thereby. By repairing or upcycling old clothes, consumers can minimize their environmental footprint and contribute to the circular economy (Dissanayake & Sinha, 2012).

Restoring old garments allows individuals to preserve cherished memories and cultural heritage associated with their clothing (Gwilt, 2014). Vintage pieces often carry sentimental value, representing milestones, traditions, or connections to loved ones. By restoring and continuing to wear these garments, individuals can honor the past while embracing sustainable fashion practices.

Importance of Recycling Clothes

1. Promotion of Individuality and Creativity

Restoring old garments allows individuals to express their unique style and creativity (Gwilt & Rissanen, 2011). Whether through repairing a beloved jacket, transforming a vintage dress into a modern masterpiece, restoration empowers individuals to create one-of-a-kind pieces that reflect their personality and values.

2. Embrace of Slow Fashion

In contrast to the fast fashion model of constant consumption and disposal, restoration encourages a more mindful and deliberate approach to clothing (Pookulangara & Shephard, 2013). By investing time and effort into restoring old garments, individuals cultivate a deeper appreciation for the craftsmanship and quality of their clothing, fostering a culture of slow fashion that prioritizes durability, longevity, and ethical consumption.

3. Empowerment of Do-It-Yourself Culture

Restoration fosters a sense of empowerment and self-sufficiency by encouraging individuals to take control of their wardrobe and become active participants in the fashion process (Twigger Holroyd, 2017). Through learning basic sewing skills, experimenting with garment alterations, and exploring creative techniques, individuals can reclaim agency over their clothing choices and reduce reliance on mass-produced fashion.

Reviving Old Clothes with Tie and Dye and Aso oke

Tie and dye, an ancient textile art form, offers a sustainable solution to repurpose old clothes, breathing new life into discarded garments (Varadarajan & Venkatachalam 2016). This traditional practice involves tying or binding fabric in various patterns before applying dye, resulting in vibrant, contemporary designs that transform worn-out textiles into unique pieces of wearable art.

By harnessing the techniques of tie and dye, individuals can revive old garments and create visually striking patterns that add character and style to their wardrobe (Simeon & Vijayalakshmi 2023). From simple geometric motifs to intricate tie-dye designs, the possibilities are endless, allowing for endless creativity and experimentation.

In addition to tie and dye, the upcycling of Aso oke, traditional Yoruba garments worn for special occasions, presents another innovative approach to transforming old textiles into new, functional pieces (Alabi & Sokoya 2018). Aso oke often accumulates in wardrobes, taking up valuable space and contributing to clutter. To upcycle Aso oke, individuals can explore a range of creative possibilities, such as transforming them into stylish accessories like bags, pouches, or headbands, or trendy wears like jackets and trousers. Furthermore, Aso oke can be repurposed into home decor items such as throw pillows, wall hangings, or table runners, adding a touch of cultural heritage and personality to living spaces (Nwauche, 2017).

Rejuvenating Acceptance of Local Clothing Ideas for Functional and Trendy Apparel

In today's era of globalization and rapidly evolving fashion trends, rejuvenating the acceptance of local clothing ideas is paramount for fostering cultural identity, promoting sustainability, and stimulating economic growth. This endeavor is especially crucial in appealing to the tastes of the younger generation, such as Generation Z (Gen Z), who wield considerable influence in shaping consumer trends and cultural norms. Engaging them effectively can address sustainability challenges by aligning initiatives with their values.To facilitate the rejuvenation of local clothing ideas, various strategies can be implemented.

1. Educational campaigns play a pivotal role in raising awareness about the environmental impact of textile waste and the benefits of upcycling clothing items. By educating consumers, especially the younger generation, about the history, symbolism, and production techniques of local textiles like Aso Oke and Adire, a deeper appreciation for indigenous craftsmanship can be fostered. Fashion shows, exhibitions, and cultural events showcasing the versatility and creativity of traditional textiles can also serve to attract wider attention and interest.
2. Workshops and classes on upcycling techniques, particularly focusing on Aso Oke and tie-dye methods, provide individuals with practical skills to transform old textiles into personalized items. Offering customization services allows individuals to repurpose their old Aso Oke into personalized garments or accessories tailored to their preferences, adding a unique and meaningful touch to their wardrobe.
3. Collaborative projects with local artists, designers, or fashion brands can result in limited-edition collections or artworks using donated Aso Oke, with proceeds supporting community and sustainable fashion initiatives. Competitions and challenges encourage creativity in upcycling Aso Oke, with social media campaigns amplifying success stories and inspiring broader participation in recycling efforts.
4. Partnering with charitable organizations or initiatives that repurpose donated Aso Oke into new garments or accessories, with proceeds supporting community development projects or charitable causes, offers a sustainable solution. Additionally, implementing reward programs where individuals earn incentives for donating clothing items for recycling can further incentivize participation and support.

Enhancing functionality and sustainability through Tie-dye and Aso oke upcycling

Individuals and brands can elevate the functionality, comfort, and versatility of their clothing by incorporating these structural enhancements into recycled Aso oke and tie-dyed garments, while promoting sustainability and creativity in fashion design. These will improve local products to match the taste of the gen Z.

1. To enhance the durability and longevity of recycled Aso oke and tie-dyed garments, reinforcing seams and stitching is essential. This ensures they withstand the rigors of daily wear and tear, prolonging their lifespan and reducing the need for frequent replacements.
2. Incorporating adjustable elements such as drawstrings, elastic bands, or button closures adds a layer of customization to recycled clothing items. This allows wearers to achieve a personalized fit and enhanced comfort, catering to the individual preferences of the younger generation.
3. Functional pockets and storage compartments are integral additions to recycled garments, providing practicality and convenience for carrying essentials such as keys, phones, or small accessories. This feature aligns with the lifestyle needs of today's youth, who value both style and functionality in their clothing choices.
4. Convertible designs offer versatility and value to the wearer, allowing recycled garments to be worn in multiple ways. Whether it's a reversible jacket, detachable sleeves, or convertible skirt, these adaptable pieces cater to the dynamic lifestyles of the younger generation, who seek versatility and functionality in their wardrobe.
5. Enhancing the thermal insulation properties of recycled clothing items ensures warmth and comfort in cold weather conditions. This feature addresses the practical needs of the younger generation while also promoting the longevity of the garment through season-to-season wear.
6. Incorporating modern silhouettes, cuts, and styles breathes new life into traditional textiles like Aso Oke and Adire. Tailored suits, fitted jackets, and trendy joggers appeal to the fashion preferences of today's youth, blending traditional craftsmanship with contemporary flair.
7. Exploring innovative dyeing, printing, and embellishment techniques adds a contemporary twist to traditional textiles. Unique patterns and designs on Aso Oke and Adire resonate with the artistic sensibilities of the younger generation, who appreciate creativity and individuality in their clothing.
8. Combining Aso Oke and Adire with other fabrics such as denim, leather, or knitwear creates eclectic and textured garments that cater to Gen Z's love for mix-and-match styling. This fusion of materials offers endless possibilities for creating distinctive and expressive looks.
9. Offering customization services allows customers to personalize their clothing items with bespoke details, monograms, or embroidery. This caters to Gen Z's desire for self-expression and individuality, empowering them to create garments that reflect their unique personality and style preferences.

Support for Local Production of Sustainable Clothing and Traditional Attire

In the face of the mounting environmental and social costs associated with the fast fashion industry, there is a growing movement towards supporting local production of sustainable clothing and traditional attire. This approach not only promotes eco-friendly practices but also aims to preserve cultural heritage and empower local communities paving the way for a more conscious and mindful approach to clothing consumption.

1. Government intervention is crucial in promoting sustainable fashion practices. This includes enacting policies and regulations that incentivize sustainable clothing production and consumption, such as tax breaks for eco-friendly practices and standards for ethical sourcing and production.
2. Setting an example by wearing traditional attire for public appearances and cultural ceremonies demonstrates pride in cultural heritage, inspiring others to embrace traditional clothing as a form of self-expression and identity. Encouraging the wearing of these attires for official functions such as School Uniforms, Presidential entourage, final defense, convocations, and conferences showcases our cultural heritage on a global stage, reinforcing our identity and promoting cultural diversity.
3. Financial support, grants, or low-interest loans to local designers, artisans, and textile producers enable them to invest in sustainable production methods, technology upgrades, and skill development programs, fostering innovation and competitiveness in the industry.
4. Investing in infrastructure improvements, such as textile recycling facilities and sustainable manufacturing hubs, supports the growth of sustainable fashion industries, reducing environmental impact and promoting circularity in the fashion supply chain.
5. Facilitating market access for local sustainable clothing brands through trade shows, exhibitions, and export promotion initiatives promotes economic development while also showcasing traditional attire through cultural festivals and fashion weeks, celebrating our cultural heritage and promoting cultural exchange.
6. Celebrities, influencers, and influential figures play a crucial role in promoting sustainable fashion and traditional attire. Through social media campaigns and public endorsements, they can amplify the message of sustainability and cultural pride. They can also advocate for initiatives that support sustainable fashion and upcycling at the grassroots level influencing consumer behavior and driving positive change in the industry.

CONCLUSION

In conclusion, restoration represents a powerful tool for promoting sustainability, preserving memories, fostering creativity, and empowering individuals in the realm of fashion. By embracing the concept of restoration and breathing new life into old garments, consumers can play a meaningful role in creating a more ethical, environmentally conscious, and stylish wardrobe for themselves and future generations.

Tie and dye and the upcycling of Aso oke offer innovative and sustainable solutions for repurposing old clothes and textiles, breathing new life into discarded garments and transforming them into vibrant, contemporary pieces. By embracing these ancient practices and exploring creative possibilities, individuals can contribute to a more sustainable and environmentally conscious approach to fashion and design.

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SAFEGUARDING AFRICAN TREES: CHALLENGES AND STRATEGIES FOR BIODIVERSITY CONSERVATION AND CLIMATE RESILIENCE

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ABSTRACT

Trees play a crucial role in maintaining ecosystem stability and mitigating the effects of climate change. Africa forests are repositories of biodiversity ranging from tree species to lower plants and several beneficial faunas that support ecosystem balance. However, the ongoing processes of urbanization and industrialization have led to a decline in tree populations across Africa. Of greater concern is the alarming increase in the incidence of insect pests and pathogens within African forests, which is primarily attributed to rising temperatures resulting from greenhouse gas emission s. Following an appraisal of literatures and online databases, this review highlights the urgent need to address these challenges in African forest conservation to improve resilience in global climate change scenarios. Indigenous trees in natural forests, agroforestry systems, and exotic species are affected. Thus, worsening the existing threats posed by climate change to natural resources, economic growth, and ecosystem conservation efforts. Pest and disease invasions continue to disrupt sustainable forestry practices, reduce productivity in agroforestry, and endanger biodiversity across the continent. The natural and agroecosystems of sub-Saharan Africa are increasingly vulnerable to climate change, with potentially devastating consequences. Therefore, integrated and coordinated approaches are essential to enhance biodiversity conservation, improve biosecurity, implement biological pest control measures, and develop tree resistance to abiotic stressors. Efforts to intensify tree cultivation in Africa, particularly through the domestication of tree species and the establishment of gene banks for germplasm conservation, are paramount. Strict enforcement measures are also necessary to combat illegal logging, especially within protected areas. Collaboration with international agencies and active engagement with local communities are crucial components for achieving sustainable protection of natural resources and biodiversity conservation on the African continent.

Key words: *Biodiversity conservation, Climate change mitigation, Indigenous tree species, Biosecurity*

INTRODUCTION

Trees are crucial for Africa's future (Graziosi *et al.*, 2020). African tropical forests and woodlands are rich in biodiversity, with various endemic flora and fauna compared with temperate forests. Vegetation consisting of trees, shrubs, and herbaceous species provides a plethora of resources, including timber-based products such as woods for various industrial processes and non-timber forest products (NTFPs), which are used as medicines and foods by local communities (Lowore et al., 2018). In addition, tree components of the forest are vital to ecosystem functioning via the regulation of biogeochemical cycles and carbon sequestration while also providing a suitable habitat for microorganisms and animals. However, the survival of African trees and ecosystem balance are threatened by anthropogenic activities and global climate change. A major threat to forest ecosystems driven by human action is deforestation either for conversion to agricultural land or logging to obtain raw materials for urbanization and industrialization (Brandt et al., 2017). In addition, land degradation, intensified by unsustainable land use practices, further undermines the resilience of African trees. Invasive pest attacks intensified by climate change impacts, such as altered rainfall patterns and increased temperatures.

In advanced countries, most forests are managed, but this is not usually the case in developing countries like Nigeria as relatively few forests are formally managed (Ladipo, 2010). Forest degradation refers to the impoverishment of standing woody land mainly caused by human activities (FAO, 2010). This is the result of the overexploitation of forest resources by humans. Much timber production in Africa still comes from natural forests, with most forest management efforts aimed at establishing plantations of exotic trees such as *Tectona grandis* and *Gmelina arborea*. Such plantations are left for several years, after which they are cut down without replacements. This has also generated public pressure to manage forests. Furthermore, increasing dependence on wood for fuel and building materials, when combined with population growth, contributes to the increasing rate of forest and woodland destruction (Brandt et al., 2017). Following these pressures and with increased timber production, forests are now in demand for other goods and services. In fact, the goals of forest management are broadening.

The emphasis is not only on timber yield but also on broader sustainable forest management. This will ensure that the forest can still perform several ecosystem functions such as providing fruits, fungi, medicinal plants, and animals; soil and water conservation; biodiversity conservation recreation; and landscape amenities. Moreover, sustainable forest management entails balancing today's needs with those of future generations. This implies a greater role of foresters in broader land-use decision-making as well as greater participation of non-forestry interest groups in setting the objectives of forest management (Wu et al., 2022). Human beings tend to use nature's free gift in a manner that diminishes its supply and value without adequate replenishment measures. The mentality is "it will always be available", however continuous exploitation without replenishment will lead to extinction. Therefore, for development activities to meet human needs, there must be a trade-off between development and forest conservation for the forest to contribute meaningfully to sustainable development in Nigeria. Targeted actions toward sustainable forest management and conservation to develop measures that will strike a balance between ecological protection and economic and societal development are of utmost necessity (Ihemezie et al., 2021).

Recent climate change with an increase in global temperature has led to increased incidences of pests in both economic trees and plants, with poor and developing countries being the most adversely affected. The current review resonates with two of the United Nations Sustainable Development Goals; Climate action (Goal 13), which seeks to take urgent action to combat climate change and its impact (UN, 2022). Second is life on land (Goal 15), which seeks to protect, restore, and promote the sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, halt and reverse land degradation, and halt biodiversity loss. There is a crucial need to strengthen efforts that are targeted at the protection, conservation, sustainable use, and production of forest goods and services (UN, 2022) and to ensure the continual availability and restoration of extinct, threatened, and near threatened species. This review explores the multifaceted challenges facing African trees and identifies strategies for their conservation to safeguard biodiversity and enhance climate resilience.

Method of Literature Search

Keywords such as biodiversity conservation, climate change mitigation, indigenous tree species, and biosecurity were used to obtain articles from various databases. A comprehensive review of the literature and case studies was conducted to highlight the importance of protecting African trees and provide insights into effective conservation approaches.

Major Trees of the African Continent

The world's tree flora is estimated to be approximately 100,000 species and over 17,000 tree species are at risk from rapid global change (Boonman et al., 2024). African forests host various floristic vegetation of different canopy layers, and of note are native and exotic tree species that have been introduced from other regions of the world. These trees are distributed across different regions of the continent, although they exhibit variations in species type and some morphological differences.

Table 1: Overview of Threatened Tree Species in Africa

Countries	**Threatened tree species**
Benin	*Afzelia africana, Khaya senegalensis, Pterocarpus erinaceus*
Burkina Faso	Acacia senegal, *Anogeissus leiocarpus, Adansonia digitata, Bombax costatum, Faidherbia albida, Khaya senegalensis, Parkia biglobosa, Vitellaria paradoxa, Pterocarpus erinaceus, P. lucens*

Cameroon	*Acacia nilotica, Azadirachta indica, Khaya senegalensis, Dalbergia melanoxylon*
Chad	*Azadirachta indica, K. senegalensis, Parkia biglobosa, Vittelaria paradoxa , Ziziphus mauritiana*
Côte d'Ivoire	*Cassia sieberiana, Ceiba pentandra, Diospyros mespiliformis, Ficus capensis, Khaya senegalensis, Pterocarpus erinaceus*
Eritrea	*Acacia etbaica, Adansonia digitata, Boswellia papyrifera*
Gambia	*Bombax buonoposense, Khaya senegalensis, Oxytenanttera abyssinica, Parkia biglobosa, Prosopis africana, Vitex doniana, Pterocarpus erinaceus, Raphia spp*
Kenya	*Acacia tortilis, Balanites aegyptiaca, Faidherbia albida, Tamarindus indica*
Mali	*Gilbertiodendron glaudolosum, Guibourtia copallifera*
Mauritania	*Boscia senegalensis, Borassus flabelifer, Combretum micrantum, Commiphora africana,, Hyphaene thebaica , Faidherbia albida, Grewia bicolor, Khaya senegalensis, Pterocarpus erinaceus, Raphia soudannica, Tamarindus indica*
Niger	*Acacia senegal, Diospyros mespiliformis Lannea microcarpa, Prosopis Africana, Sclerocarya birrea*
Nigeria	*Bombax costatum, Guiera senegalensis, Pterocarpus erinaceus, Annona senegalensis, Anogeissus leiocarpus, Balanites aegyptiaca, Carrisa edulis, Hyphaene thebaica, Lannea bacteri, Phoenix dactylifera, Piliostigma thonningii , Ximenia americana, Ziziphus spina christii*
Senegal	*Faidherbia albida, Pterocarpus erinaceus, Dalbergia melanoxylon, Parkia biglobosa*
Sudan	*Acacia mellifera, Acacia seyal, Acacia tortilis, Adansonia digitata, Albizia amara, Albizia aylmeri, Anogeissus leiocarpus, Balanites aegyptiaca , Borassus aethiopum, Dalbergia melanoxylon, Diospyros mespiliformis, Faidherbia albida, Hyphaene thebaica, Lannea fructicosa, Sclerocarya birrea*

Togo	*Anogeissus leiocarpus, Botrichium chamaeconium Daniellia oliveri, Dorstenia walleri, Faidherbia albida Garcinia afzelia, Garcinia Kola Khaya senegalensis, Parinari sp*

Source: Forestry Department, Food and Agriculture Organization of the United Nations country reports (2001)

Recently, some of these trees have also been red-listed by the International Union for Conservation of Nature (IUCN) as endangered, threatened, and near-threatened species, indicating their conservation status and the urgency to prevent their extinction. Some of these species include *Entandrophragma candollei, Erythrophleum ivorense, Triplochiton scleroxylon, Bobgunnia fistuloides, Terminalia superba, Lophira alata, Afzelia bipindensis, Prioria balsamifera, and Milicia excelsa* (UN, 1998; Smith, K. 2020; Sosef et al., 2021)

Challenges of Sustainable Management of African Trees

Deforestation: Forest conversion to farmlands, construction of roads and buildings due to urbanization, logging for charcoal production, fuelwood, and export and production of finished wood products are the main causes of deforestation (Sedano et al., 2017). Because these are usually performed on a large scale, they remain a primary threat to African trees. Deforestation triggers soil erosion and reduces water availability, thereby worsening the effects of natural disasters such as drought spells, floods, and wild fires. Deforestation is one of the most pressing ecological challenges in Africa and poses significant threats to biodiversity, climate stability, and human well-being. Deforestation upsets the ecosystem because of the loss of habitat for various species (Mama, 2017). As forests are cleared, the biodiversity (plant, animals and microbial populations) that they harbor are also lost. Thus, a huge population of African endemic species has been lost, thus jeopardizing the resilience of ecosystems to global climate change.

Land Degradation: The development of land use systems that meet the needs of present and future generations without causing environmental degradation remains one of the major challenges we face today. For sustainable development, such land use systems must have the capacity to prevent and control any form of gross abuse or unsustainable use of land resources. Unsustainable land use practices such as indiscriminate conversion of forests to agricultural lands, urbanization, and overgrazing in protected forest areas are major contributors to land degradation and desertification in Africa and globally (Sze et al., 2021).

Increased Pest Attack: Incidences of insect pests and pathogens are increasing at an alarming rate in African forests, with a focus on indigenous trees of natural forests, agroforestry systems, and exotic trees (Pratt *et al.,* 2017). Pest-induced defoliation (leaf loss), dieback of tree stems, and whole tree mortality can result in significant changes in forest structure and composition that compromise the integrity of forest ecosystems. This is in addition to the challenges posed by climate change and threats to natural resources, economic growth, and ecosystem conservation measures. According to Wheeler and Von Braun (2013), the natural and agroecosystems of the sub-Saharan African region will be more vulnerable to climate change with attendant negative effects. Thus, employing integrated and globally coordinated approaches that enhance improved biosecurity, biological control, and tree resistance are mitigation measures for combating these invasions of African natural resources (Graziosi *et al.*, 2020).

As efforts are ongoing toward tree cultivation in Africa, pest and disease invasion still hampers sustainable plantation forestry, limits productivity in agroforestry, and threatens the biodiversity of the continent (Crous *et al.,* 2017). Examples of such pests and tree species include *Triplochiton scleroxylon, which* is affected by *Diclidophlebia eastopi*; *Terminalia spp* which is affected by *Apate monachus* (common borer); African teak *Milicia excel, which is* affected by *Phytolyma fusca* (African teak gall bug); and *P. lata* (Iroko gall bug) (Ugwu & Omoloye, 2014). This calls for action, and as such, long- term efficient and effective management options that employ biological control of pest disease and pathogens, innovative silviculture practices, and selection of resistant trees for plantation could be the much-needed solution (Bardin *et al.,* 2017). Efforts have been made to domesticate tree species and conserve their germplasm in Africa, with numerous field gene banks of important tree species established across African eco-regions (ICRAF, 2013), thus presenting a valuable resource for selecting pest- and disease-resistant trees.

Invasive Tree Species: Invasive trees are non-native species that are introduced into new environments, where they proliferate and outcompete native species. The introduction of exotic plant species from other geographical locations disrupts native ecosystems, outcompetes indigenous vegetation, and alters ecological dynamics (Raphela & Duffy, 2022). Invasive species pose a significant threat to the survival of African trees by rapid colonization and displacement of indigenous flora, thereby causing changes in forest structure and reducing biodiversity. In addition, some invasive species are vectors of pests and diseases and release allelochemicals that hinder the development of other plants native to the region.

Climate Change Impacts: Global climate change effects such as high temperatures, altered rainfall patterns, and other extreme weather events have detrimental effects on Africa tree health (Wingfield et al., 2015). These effects range from soil drying and low nutrient availability to increased proliferation of pest and disease attacks. With changes in species distribution and re-establishment rates and alteration in the entire physiognomies, morphological characteristics of tree species, and eventual mortality, the resilience of forest ecosystems is greatly affected. Extreme weather events, such as droughts, heatwaves, and storms, are becoming more frequent and intense because of climate change (FAO, 2010). In recent times, forest fires, heatwaves, and storms have become more frequent global challenges, causing widespread damage to forest ecosystems and disrupting their ecological processes (Qu et al., 2024). Adaptation measures, such as promoting climate-smart agriculture, restoring degraded landscapes, and implementing sustainable forest management practices, are crucial for building resilience to the impacts of climate change and ensuring the long-term viability of forest ecosystems (Pradhan et al., 2023).

Strategies for Safeguarding African Trees

Strategic measures for safeguarding African trees require a multifaceted and concerted effort that integrates ecological, social, and economic considerations to ensure their conservation and sustainability for current and future generations. First, promoting sustainable forest management includes adopting approaches such as selective harvesting of mature trees, reduced logging, and concerted community-based protection of forest areas (Edwards et al., 2019). This will foster adequate management and strike a balance between the conservation of biodiversity and the sustainable use of forest resources. Afforestation policies such as “cut a tree and plant two as a replacement” will promote forest regeneration in Africa. Second, strict measures preventing unwholesome and unauthorized entry into protected forest areas and Conservation Reserves must be enforced by forestry organizations and government bodies: this is critical for African forest reserves, which are critical habitats and biodiversity hotspots for endangered species (Ikehi et al., 2015). Furthermore, afforestation and reafforestation efforts must be targeted more at native species to prevent the spread of invasive species and control pest and disease attacks. In incidences of pest and disease attacks, development of improved germplasms; biological and eco-friendly means such as introduction of predators of such pests and application of biopesticides of plant origin may present a means of controlling their spread.

The agroforestry practice, which has been adopted in some forest reserves in Nigeria, is a means of sustainable land management (Betts et al., 2021). This system allows the intercropping of food crops among trees in plantation forest and is beneficial in two ways. First, the land is maximized as the trees are not cut down but the crops are grown in between. In addition, the trees provide shade, and the shed leaves are used as mulch and biofertilizer to enhance crop growth. Implementing sustainable land management practices, such as agroforestry, reforestation, and soil conservation measures, can mitigate land degradation and restore degraded ecosystems. Hence, promoting sustainable agriculture and land-use planning initiatives is crucial for preserving the integrity of African landscapes (UN, 2022).

Third, strengthening the resilience of African trees to the impacts of climate can be achieved through a combination of climate adaptation and mitigation measures, such as climate-smart forestry practices with resilient tree species and genetic diversity conservation via ex situ germplasm conservation (Dawson et al., 2014). Finally, local community engagement is critical for safeguarding African forests. Until today, certain regions of Africa still hold sacred groves that contain endemic species that are protected from marauders by local and traditional people. Involving local stakeholders in decision-making processes and empowering the surrounding communities is a major means to the long-term stewardship of African trees.

CONCLUSION

Safeguarding African trees is imperative for preserving biodiversity, maintaining ecosystem services, and enhancing climate resilience across the continent. Loggers must be mandated to perform proper afforestation and reforestation to ensure the conservation of valuable forest resources. Enforcement of selective harvesting that ensures that only mature trees are cut by forest loggers is required. More national parks where logging activities are highly prohibited should be created in African nations to achieve a high level of conservation. In addition, establishment of gene banks for conservation of germplasm of important tree species must be promoted. A synergistic effect must be achieved between social and economic advantages and environmental health in forest resource utilization. It is only through collective action and shared commitment that we can secure the future of African trees for generations to come and ensure the continued vitality of our forest to support the well-being of human, flora and fauna communities.

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AWARENESS AND ACCEPTABILITY OF SWEET POTATO-COWPEA CHIN-CHIN IN COMPARISON TO WHEAT FLOUR CHIN-CHIN

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ABSTRACT

Chin-chin is a popular snack across Nigeria made from wheat flour and fried with fats/oils or sometimes baked. It is regarded as being nutritionally poor, as cereal wheat lacks essential amino acids such as lysine and threonine, hence substituting wheat flour with cheap staples, such as cereals, tubers and pulses; helps increase the nutritional quality of food products. However, chin-chin made from sweet potato and cowpea composite flour has not gained a high level of popularity and acceptance from the public compared to wheat flour chin-chin. Only a few percentage of people know about the potential of making confectionary and snacks food using sweet potato and the range of essential nutrients in the sweet potato flour that is lacking in processed wheat flour and how this sweet potato and cowpea flour can be easily produced and raw materials readily available in the open market. This study was aimed at evaluating the overall acceptability of chin -chin made with sweet potato – cowpea flour and the awareness of sweet potato – cowpea flour chin-chin as compared to the popular wheat flour chin-chin. The study was carried out in the University of Ibadan. Structured questionnaire (sensory evaluation form) was administered to respondents. The overall acceptability showed that sweet potato – cowpea flour was well accepted by respondents. The color, taste, aroma, texture of the snack were rated high by respondents. The level of awareness and consumption of sweet potato –cowpea flour chin-chin was assessed and it was observed that a large percentage of the respondent were not aware that chin-chin can be made with any other type of flour (in this case sweet potato-cowpea flour) other than wheat flour and have never eaten sweet potato –cowpea flour chin-chin.

Key words: *Awareness, Sensory evalua5tion, Texture, Zoological garden*
Word count: *283*

INTRODUCTION

Snacking habits, is defined as any eating event asides main meals; no matter the amount or the kind of food eaten (Hess *et al*., 2016).These eating styles are mostly referred to as "snacks" or "snacking" (i.e., eating a snack) (Hess *et al*., 2016). A basic view of snacks is referred to as type of foods that are eaten between the main traditional meals of the day, which are breakfast, lunch, and dinner (Forbes *et al*., 2016).

Sweet potatoes are dicotyledonous plants and essential crops in terms of complete biomass. Sweet potato production was recorded to be 112.8 million tons (in 115 countries) in 2017, and China is the main producer, followed by Nigeria and Tanzania, Indonesia, and Uganda (FAOSTAT, 2019).

Cowpea is also called southern pea, black eye pea, crowder pea, lubia, niebe, coupe or frijole. It belongs to the family Fabaceae and sub-family Faboideae (Agbogidi, 2010). Asides Nigeria which cultivate the most amount of cowpea grains yearly at an estimated 2.14 million metric tons, USA, Peru, Serbia, Sri Lanka, China were among the world-leading cultivators of cowpea in the last three years (FAOSTAT, 2017

According to Abiodun *et al.*, (2017) *Chin-chin* is a pan/deep-fried golden brown crispy wheat flour snack, famous in Nigeria amid several age ranges. It is abundant in various shapes and sizes. Its popularity has increased its industrial production and marketing of the product by entrepreneurs. *Chin-chin* is an indigenous Nigerian snack made with wheat flour, butter, milk and eggs from which dough is made which is then fried until it is golden brown and crisp. It is a very common snack across Nigeria and some part of western Africa. It is sweet to taste, a bit hard and might be said to be a firmer type of doughnut. Sometimes, the *chin-chin* might even be made up of cowpeas and at other times it may be made by baking instead of frying (Adegunwa *et al*., 2014). Nutmeg might also be used as a flavor alongside other conventional baking materials used in its preparation.

STATEMENT OF PROBLEM

Due to the dependency of consumers on snacks, healthier and more nutritious snacking alternatives are paramount to sustain a healthy diet. Wheat flour is one of the key raw materials in the making of numerous foods and it is common in many countries diets (Teemu *et al*., 2017).The efficient supply of flour influences the economic and political issue of most countries (Teemu *et al*., 2017**)**. Hence wheat has a large effect on the nutritional quality of food eaten by a huge amount of people and subsequently on their health. However, using sweet potato-cowpea composite flour in the production of the popularly consumed *chin-chin* snack will not only increase the vitamin A and protein content of the snack but will also create a healthier snacking option. According to Ahmed *et al*., (2010), past studies have shown the potential use of sweet potato in noodles and other wheat-based baked products, the manufacturing of sweet potato and cowpea flour mix will enhance their consumption for adequate nutritional status for all age brackets. There is abundance in the availability of sweet potato and cowpea for flour production, this also contribute to the consumption of finished products produced in Nigeria from farm to table (FAOSTAT, 2017).

Chin-chin is a popular snack across Nigeria made from wheat flour and fried with fats/oils or sometimes baked (Abiodun *et al*., 2017). However, *chin-chin* made from sweet potato and cowpea composite flour has not gained a high level of popularity and acceptance from public compared to wheat flour *chin-chin*. Only a few percentage of people know about the potential of making confectionary and snack food using sweet potato and the range of essential nutrients in sweet potato flour that is lacking in processed wheat flour and how this sweet potato and cowpea flour can be easily produced and raw materials readily available in the open market (Suarez *et al.*, 2016).

JUSTIFICATION

Presently, consumers' knowledge of the advantage of consuming high quality and healthy foods also called functional foods, that is, foods that their raw materials promote health benefits beyond the regular nutritional needs, is rising (Ndife and Abbo, 2009). *Chin-chin* made with sweet potato-cowpea composite flour is a good example of snack that can be used to improve the nutritional status of consumers; as it not only contains vitamin A and protein, it provides a healthier alternative as compared to the popular wheat flour *chin-chin*. This snack should be developed and exploited.

Asides being a rich source of calories and other nutrients, wheat are regarded as being nutritionally poor in protein because, cereal lack essential amino acids such as lysine and threonine (Shfali and Sudesh, 2002). Therefore, substituting wheat flour with cheap staples, such as cereals, tubers and pulses, helps increase the nutritional quality of food products

The creation of appetizing processed products from sweet potatoes will contribute to raising awareness on the potential of the crop (Iese *et al*., 2018).Therefore this study is geared towards creating awareness and acceptability of Sweet potato flour fortified with cowpea flour in the making of confectionaries at bakeries and at home exploring different recipes for different snack food. The discoveries of this study would also show the future application of sweet potato and cowpea flour blend in the confectionery and snack food as an alternative for wheat flour. The organoleptic properties (colour, aroma, taste, texture) of *chin-chin* would be looked at; this could help to increase its recognition within the University of Ibadan particularly among visitors at the University of Ibadan Zoological Garden. Hence, the objective of the study determines the awareness of chin-chin made with sweet potato and cowpea flour and evaluates the overall acceptability of chin-chin made with sweet potato and cowpea flour among visitors in the University of Ibadan zoological garden.

MATERIALS AND METHODS

Study Area

The research was carried out in the Zoological Garden of the University of Ibadan. It is located five miles (8 kilometer) from the center of the city of Ibadan in western Nigeria; it covers a total land area of 1,032 hectares and lies between latitude 7.43N and longitude 3.88E.

PURCHASE OF MATERIALS

Sweet potatoes tubers (*Ipomoea batatas*) and cowpea (*vigna unguiculata*) were purchased from Bodija market, Ibadan, Oyo State. Some other ingredients such as butter, eggs, vegetable oil, salt, nutmeg, baking powder and sugar were also purchased at the same market.

Method of Preparing the Sweet Potato-Cowpea Flour Chin-Chin

Sweet potato-cowpea composite flour chin-chin was prepared at the Department of Wildlife and Ecotourism Laboratory. The dry ingredients (800g of composite flour, 100g sugar, half teaspoon of nutmeg, Salt, half teaspoon of Baking powder) were mixed together in a bowl and set aside. 200g butter was added to dry ingredients until just combined thereafter 3 medium size eggs were mixed together thoroughly, the egg mixture and the milk was poured into the dry ingredients until the dough is formed. The dough was kneaded gently and double turned and allowed to rest for five minutes. The dough was rolled out on a board and cut into little square shapes and was placed in a pan and sprinkled with flour to prevent sticking. It was then baked in an oven at 180^0 c for about 30-35 minutes until slightly brown and firm. The composite flour was used in the ratio 80:20 (Sweet potato flour to cowpea flour).

METHOD OF DATA COLLECTION

The method of data collection used for the of sweet-potato cowpea chin-chin, was the questionnaire for sensory evaluation and proximate analysis of samples carried out at the laboratory

Sensory Evaluation

The Sensory evaluation involves that was accessed are color, taste, flavor, aroma, texture and overall acceptability using a 9-point hedonic. Judges (92 visitors at the University of Ibadan zoological Garden) were asked to rank the samples according to their preference using; 1 = dislike extremely, 2 = dislike very much**,** 3 = dislike moderately**,** 4 = dislike slightly**,** 5 = neither like nor dislike**,** 6 = like slightly**,** 7 = like moderately, 8 = like very much, 9 = like extremely

Method of Data Analysis

The research was subjected to descriptive and inferential statistics

RESULTS AND DISCUSSION

Level of awareness of sweet potato-cowpea Flour Chin-chin

The study showed that many of the respondents were not aware of the snack (65.2%). It also showed that 64.1% of the respondents have never eaten the snack; while only 20.7% have eaten the snack before. The fact that most of the respondents have never eaten the snack is due to their unawareness and low publicity on the use of sweet potato flour as a good and nutritious alternative to snacks produced with wheat flour. This however attest to statements made by (Alam, 2021) that The use of sweet potato in creating functional foods gives potential ideas and collaboration with food manufacturer has begun to use sweet potato for the creation of juice, pasta, ice cream and other new food products. To date, a number of products have been created with sweet potato and requires more research for marketing.

Table 1: Distribution by Respondents' Awareness of Sweet potato-Cowpea flour and

Variable	Frequency	Percentage %
Are you aware of sweet potato-cowpea chin-chin		
Yes	32	34.8
No	60	65.2
Total	92	100
Have you ever eaten sweet potato-cowpea chin-chin		
Yes	19	20.7
No	59	64.1
Not sure	14	15.2
Total	92	100
If yes, how often do u eat it		
Daily	0	0
Weekly	1	5.3
Monthly	0	0
Occasionally	3	15.8
Rarely	15	78.9
Total	19	100
Do you know what chin-chin is originally made from		
Yes	73	79.3
No	9	9.7
Not sure	10	10.8
Total	92	100

Source: Field Survey 2023

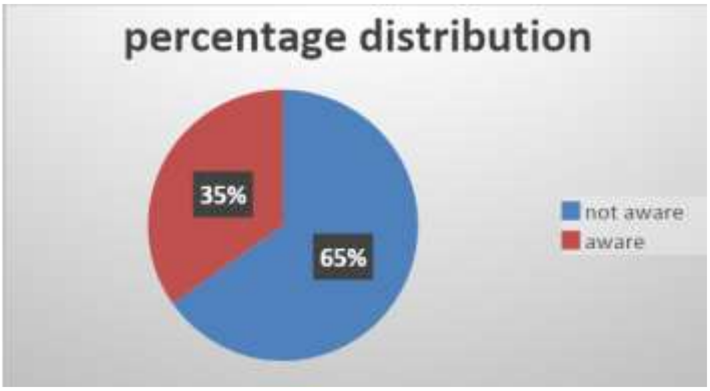

Figure 1: Percentage distribution Level of awareness of sweet potato-cowpea Flour Chin-chin

Level of acceptability of sweet potato- cowpea flour chin-chin (t_1) and wheat flour Chin-chin (t_2)

It was also observed from this study that sweet potato cowpea flour chin-chin was more accepted by the respondents in terms of all sensory characteristics than wheat flour chin-chin. Based on level of preference, 68.6% of respondent prefer sweet potato cowpea flour chin-chin against 31.4% preference of wheat flour chin-chin. This shows the potential of sweet potato composite flour as a readily available alternative to wheat flour in chin-chin production.

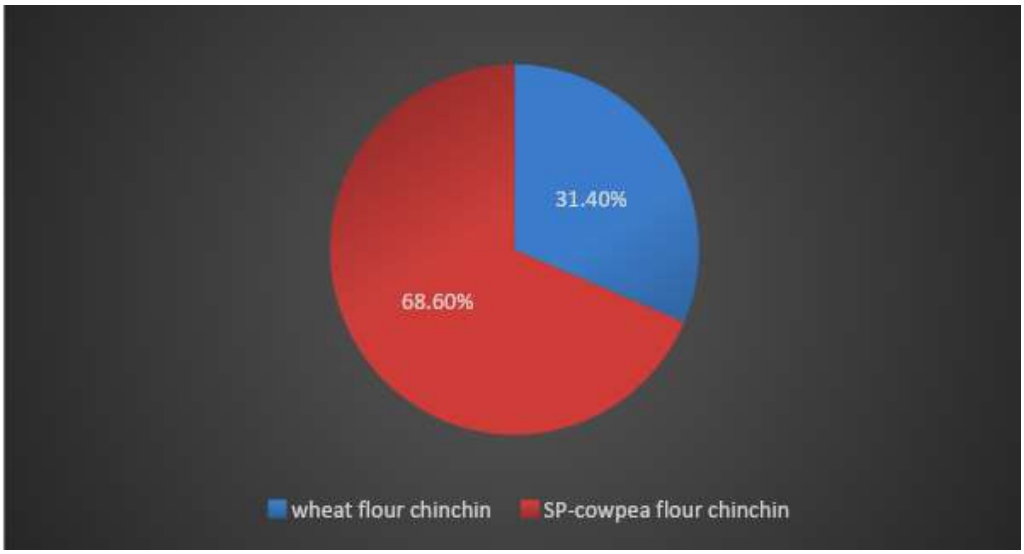

Figure 3: distribution of acceptability of sweet potato-cowpea Flour chin-chin among respondent

Table 2: Overall Acceptability

Variables	t_1 Frequency (t_1)	Percentage (%)	t_2 Frequency (t_2)	Percentage (%)
Dislike Extremely	3	3.2	1	1.0
Dislike Very Much	0	0	0	0
Dislike moderately	2	2.2	0	0
Dislike Slightly	2	2.2	3	3.2
Neither Like nor Dislike	10	10.9	17	18.5
Like Slightly	10	10.9	9	9.7
Like Moderately	16	17.3	25	27.1
Like Very Much	19	20.7	16	17.3
Like Extremely	30	32.6	21	22.8
TOTAL	92	100	92	100

Source: Field Survey 2023

OVERALL ACCEPTABILITY LEVEL OF *CHIN-CHIN* MADE WITH SWEET

In this study it was found that the sweet potato-cowpea flour chin-chin was well accepted by respondents. The colour of the snack was rated 33.7% in being liked extremely by respondents and variation in its likeness shows that 30.4% like very much and 18.7% like moderately. In terms of taste, the snack was rated 28.3% in being liked extremely by respondents and variation in its likeness shows that 19.6% like very much and 28.3% like moderately. It was observed the respondents liked the aroma as 33.7% liked it extremely with variation in likeness of 23.9% and 15.7% liking it very much and moderately respectively; and this may be due to the presence of cowpea which enhanced the aroma greatly. The soft texture of the snack was also liked extremely by 30.4% of respondent and liked very much and moderately by 18.5% and 16.3% respectively. The plain transparent product packaging was also like by respondents as 38% liked it extremely and it varied in likeness as 14.1 like very much and 27.1% like moderately.

CONCLUSION AND RECOMMENDATIONS

This study concluded that the sensory attribute of sweet potato-cowpea flour chin-chin is related to its acceptability. The sensory attribute of sweet potato-cowpea flour chin-chin is related to its acceptability and that there is relationship between the product packaging, colour, taste and the overall acceptability of the product. This research also showed that visitors (respondents) at the University of Ibadan Zoological Garden accepted chin-chin made with sweet potato-cowpea flour to a favourable extent in relation to wheat flour chin-chin. This concludes that Sweet potato-Cowpea flour chin-chin is a suitable alternative to the consumption of wheat flour chin-chin. More study on the acceptability of snacks made with sweet potato-cowpea flour should be carried out so as to create awareness of sweet potato flour. Awareness of the potential of sweet potato-cowpea flour as a nutritious and healthy alternative to wheat flour should be carried out.

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PRODUCTION NEEDS OF SOYBEAN FARMERS IN NIGER STATE, NIGERIA

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ABSTRACT

The study examined production needs of soybean farmers in Niger State, Nigeria. A five-stage sampling procedure was used to select 130 respondents for this study. Data collected with the aid of questionnaire were analyzed using descriptive statistical tools like mean, percentage, frequency counts, standard deviation and inferential statistics like PPMC. Majority of the respondents were male (76.9%), had no formal education (31.5%) and used personal savings for their production (67.7%). Respondents had mean age of 41 ±8.6 years, years of farming experience of (24.6 ±11.1) and farm size of (1.5 ±0.9). The main benefits derived from soybean production were improved standard of living (x=1.92) and food supplement for children (x=1.83). Major constraints faced by the respondents in soybean production were insufficient working capital (x=1.70) and excessive rainfall (x=1.41). Major production needs of the farmers were herbicides (x=1.78), availability of good seeds (x=1.76) and provision of fertilizer (x=1.76). There is need for the farmers to form cooperatives in other to link up with agro inputs dealers and access credit to finance soya bean production.

Key words: *Production needs, Soybean, Constraints, Benefits and Farmers.*

INTRODUCTION

In Nigeria, 60% of deaths are related to protein energy malnutrition, particularly among children (Agada, 2014). According to Masuda and Goldsmith (2009), the average Nigerian consumes about 3.2grams of animal protein daily against the minimum requirement of 35 grams per person daily. Due to dearth of animal protein, low-income populations depend largely on plant sources such as soybean to meet their protein and other nutritional requirements (Masuda and Goldsmith, 2009). However, this is contrary to the reality on ground that low soybean yield in SSA which is attributed to poor yielding varieties, limited application of fertilisers and limited utilisation of rhizobia inoculants in soils with no history of soybean production (Woomer *et al.,* 2012).

Soybean is said to be one of the most valuable crops in the world due to its multiple uses as a source of livestock and aquaculture feed, as well as protein and oil for human diet and biofuel. It is one of the tropical leguminous crops that have showed sustained growth in all production parameters (cultivated area, yield and production) over the last four decades. Although global production has been on the rise, the estimated demand which is about 300 million tons exceeds supply by over 40 million tons (FAOSTAT, 2010). Current yield has been estimated to be less than 30% of actual production capacity, with only about 7% of arable land allocated to soybeans.

Otitoju and Arene (2007) reported that Nigerian farmers (medium-scale soybean farmers inclusive) are often being constrained by several factors which have direct or indirect effects (or impacts) on agricultural productivity and invariably on production, this constraints identified include credit inaccessibility, inadequate processing facilities, low or fluctuating price of produce, weed problem pest problem, low/poor extension services/contact, lack of skills and technical know-how, inadequate storage facilities and inadequate access to production resources such as fertilizers and herbicides.

Nigeria's domestic production of soybeans is very low compared to the rapidly growing demand by the poultry industry and vegetable oil processors. This supply deficit resulted in increase in price of soybean meal within ten months, reaching a high $670 per ton September 2011. Imports of crude vegetable oil are liberalized, and local processors now look to imports to fill the supply deficit. Davidson (2004) reported that there exist enormous market potentials in Nigeria for export trade of soybeans, soybean meal, crude vegetable oil and value-added soy-based food products. Despite, the potential of soyabeans in ensuring the food security and the income of the rural farmers there are many constraints affecting the production of the crop in the country. Tolin and Lacy (2004) reported that there are some viruses that infect soybean causing huge agronomic losses. Furthermore, Heatherly and Elmore (2004) reported insects cause serious damage such as defoliation and feeding on pods of soybean which reduce soybean yield by 65% while Agada (2014) reported shortage of farm labour as a major problem of soybean and non-availability of improved and modern technologies for soybean production. Therefore, the study was designed to investigate the production needs of soybean farmers in Niger State to boost the production of soybeans in the country.

The specific objectives were to:

a. identify the socio-economic characteristics of soybean farmers in the study area.
b. identify the benefits derived from soybean production by the respondents.
c. ascertain the constraints associated with soybean farming in the study area.
d. identify the production needs of soybean farmers in the study area.

The study assumes that no significant relationship exists between the constraints faced in soybean farming and respondents' production needs.

Material and Methods

The study was carried out in Niger State located in the North central part of Nigeria. It is bordered to the North by Zamfara State, West by Kebbi State, South by Kogi State, Southwest by Kwara State, North-East by Kaduna State and Southeast by FCT. The State also has an International Boundary with the Republic of Benin along Agwara and Borgu LGAs to the Northwest and having a population of 3,950,249 based on the 2006 census. Niger State covers a land area of 76,469.903 square kilometers which is about 10% of the total land of Nigeria. It lies on latitude 80º to 11º:30' North and Longitude 03º30' to 07 º40' East. The study population included all soybean farmers in Niger State. Multistage sampling procedure was used to select respondents for this study. The first stage involved a purposive selection of an agricultural zone out of the three agricultural zones in the state with Bida Niger State Agricultural Mechanization Development (NAMADA) Zone being selected due to the prevalence of soybean farmers in the zone. Second stage involved a random selection of 25% of the 13 blocks in the selected zone which gives 3 blocks. In the third stage, 50% of the cells in the blocks were randomly selected. The fourth stage involved a random selection of 33% of the sub-cell (villages) in each cell, to give a total of 3 villages out of 9 villages with each village having an average of 150 soybean farmers. In the last stage, proportionate sampling was used to randomly select 10% of the farmers to give a total of 135 respondents.

Measurement of Variables

Constraints was measured by presenting respondents with a list of possible constraints to soybean production to indicate the degree of severity on a three (3) point scale of very severe, severe and not a constraint with scores of 2, 1 and 0 respectively. Benefit derived from soybean production was measured with a list of possible benefits to soybean production on a three (3) point scale of highly beneficial, beneficial and not and a benefit with scores of 2, 1 and 0 respectively. The respondents were provided with likely production needs on soybeans on the three-point scale of Not in need= (0), slightly in need (1), seriously in need (2). The mean scores were used to identify the most production needs.

Result and Discussion

Socio-economic characteristics of the respondent

The result of analysis on Table 1 shows that 40.0% of the respondents were between the ages of 31 and 40 years, 32.3% were between 41 and 50 years, while 0.8% was between the ages of 21 and 30 years. The mean age was 40 years. This implies that the majority of the respondents were in their active age and energetic which can make them to be productive. This conforms to the report of Amaza *et al*., (2007) that most of the Nigerian farmers were between 30 and 50 years of age. Table 1 also reveals that 31.5% of the respondents had no form of formal education, 24.6% had primary education, 22.3% had secondary education, and 14.6% had tertiary institution while 6.9% obtained adult education. This implies that majority of the farmers possessed the basic education to understand and identify their production needs and making efforts to proffers possible solutions to it. This corroborates the findings of Olorode, Adejuwon and Oyesola (2018) that majority of rural farmers in Nigeria have formal education. Personal savings was the source of capital for (67.7%), while 20.0% sourced from friends/family, 8.5% from cooperative society and 8.0% from the bank. This implies that most of the farmers preferred to source capital from the earnings made from farming and non-farming activities as well as friends/family. This might be because cooperative societies are not really functioning and active in the study area. This contradicts the findings of Adebayo *et al*., (2008) that a large number of farmers are dependent on cooperative societies for agricultural credit. The table also reveals that 58.5% had a farm size of less than or equal to 1 hectare, 26.9% had their farm size to be between 1.1 and 2 hectares, 10% had theirs between 2.1 and 3 hectares while 4.6% had theirs between 3.1 and 4hectares. This implies that most of the respondents were small-scale farmers. This agrees with the findings of Oriole (2009) that most of the soybean farmers in Nigeria were small scale farmers, who cultivated less than 3ha of farmland. This could be as a result of self-financing and involvement in other activities aside from soybean.

Table 1: Distribution of respondents according to their socio economic characteristics

Variable	Frequency (N=130)	Percentage	Mean	STD
Age				
Less or equal 20	1	0.8		
21 – 30	16	12.3		
31 – 40	52	40.0	40.9	8.6
41 – 50	42	32.3		
51 – 60	19	14.6		
Educational level				
No formal education	41	31.5		
Primary education	32	24.6		
Secondary education	29	22.3		
Tertiary education	19	14.6		
Adult education	9	6.9		
Sources of income				
Personal savings	88	67.7		
Bank	5	3.8		
Cooperative society	11	8.5		
Friends/relatives	26	20.0		
Years of farming experience				
Less or equal to 10	14	10.8		
11 – 20	49	37.7		
21 – 30	34	26.2	24.6	11.1
31 – 40	26	20.0		
41 – 50	7	5.4		
Farm size (hectare)				
Less or equal 1	76	58.5		
1 – 2	35	26.9	1.5	0.9

2.1 – 3	13	10.0
3.1 – 4	6	4.6

Source: Field survey, 2017

Benefit derived by respondents from soybean production

The results in Table 2 reveals that the major benefits derived from soybean were improved standard of living (x=1.92), food supplement for children (x=1.83), solving problem of some human ailments like diabetes, ulcer and stroke (x=1.64) food supplements for adults (x=1.54) and increase income (x=1.36). This implies that most of the respondents derived one benefit or the other from soybean production. Benefit derived could be deduced to be on the average since mean value of only five out of the nine benefits were above the grand mean. The findings corroborate Kusuma (2015) that soybean is a good source of protein for both children and adults.

Table 2: Distribution of respondents' according to benefit derived from soybean production

Benefits	Highly beneficial		Beneficial		Not a beneficial		Mean
	Freq	%	Freq	%	Freq	%	
As food supplement for children	108	83.1	22	16.9	0	0.0	1.83
Solving problem of some human ailments e.g diabetes, ulcer and stroke	84	64.6	45	34.6	1	0.8	1.64
Poverty reduction of soybean farmers	23	17.7	82	63.1	25	19.2	0.98
Purchasing of household items such as (electronics and clothes)	25	19.2	92	70.8	13	10.0	1.09
Profit used in purchasing more land	22	16.9	71	54.6	37	28.5	0.88
For feeding of Livestock	57	43.8	60	46.2	13	10.0	0.88
As food supplement for adults	73	56.2	54	41.5	3	2.3	1.54
Increase income	47	36.2	83	63.8	0	0.0	1.36
Improve standard of living	23	17.7	102	78.5	5	3.8	1.92
Grand mean							**1.35**

Source: Field survey, (2017)

Constraints faced by respondent in soybean production

Result of analysis of constraints faced by soybean farmers in the study area as presented on Table 3 reveals that the highest ranked constraints faced by the farmers were insufficient working capital (x=1.70), excessive rainfall (x=1.41), inadequate extension officer (x=1.27), unavailability of land/space (x=1.25), inadequate sources of information (x=1.21) and unavailability of manual labour (x=1.19). The result shows that the farmers need capital for their production; it also shows that climate change is a major constraint to the production of soybean in the study area. This contradicts the finding of Agada (2015) that marketing problem is the most severe constraints faced by soybean farmers in Nigeria.

Table 3: Distribution of constraints faced by respondent in soybean production

Constraints	Very severe		Severe		Not a constraints		Mean
	Freq	%	Freq	%	Freq	%	
Pest and diseases	55	42.3	24	18.5	51	39.2	1.03
Excessive rainfall	57	43.8	70	53.8	3	2.3	1.41
Insufficient working capital	97	74.6	27	20.8	6	4.6	1.70
Inadequate source of information	35	26.9	87	66.9	8	6.2	1.21
Marketing problem	30	23.1	76	58.5	24	18.5	1.04
Inadequate extension officers	48	36.9	69	53.1	13	10.0	1.27
Unavailability of land/space	44	33.8	75	57.7	11	8.5	1.25
Drought	26	20.0	89	68.5	15	11.5	1.08
Non-availability or modern equipment	18	13.8	55	42.3	57	43.8	0.70
Non-availability of seeds	28	21.5	28	21.5	15	11.5	1.10
Unavailability of manual labour	33	25.4	89	68.5	8	6.2	1.19
Lack of threshing equipment	26	20.0	87	66.9	17	13.1	1.07
Lack of knowledge on soybean cultivation	32	24.6	83	63.8	15	11.5	1.13
Grand Mean							**1.17**

Source: Field survey, (2017)

Production needs of the respondents on soybean production

Result of analysis of production needs of the respondents as presented on Table 4 reveals that the highest ranked production needs were herbicides (x=1.78), availability of good seeds (x=1.76), provision of fertilizer (x=1.76) and good bags/sacks (x=1.75) for storage of bean. The result implies that weed is really disturbing the soybean farmers in the study area which requires the use of herbicides. It could be deduced that soybean farmers still plant is local varieties that need fertilizer to germinate and produce well.

Table 4: Distribution of respondents according to production needs on soybean

Production needs	Serious need		Slight need		Not in need		Mean
	F	%	F	%	F	%	
Availability of good seed	100	76.9	29	22.3	1	0.8	1.76
Provision of fertilizer	103	79.2	23	17.7	4	3.1	1.76
Fertilizer application	47	36.2	67	51.5	16	12.3	1.24
Pest and diseases control	96	73.8	34	26.2	0	0.0	1.74
Threshing machines	86	66.2	43	33.1	1	0.8	1.65
Storage facilities	73	56.2	55	42.3	2	1.5	1.55
Availability of Herbicides	101	77.7	29	22.3	0	0.0	1.78
Crop rotation	28	21.5	86	66.2	16	12.3	1.09
Irrigation	22	16.9	45	34.6	63	48.5	0.68
Early planting	28	21.5	67	51.5	35	26.9	0.95
Shift to different farm site	42	32.3	79	60.8	9	6.9	1.25
Training and workshop	77	59.2	50	38.5	3	2.3	1.57
Information on adoption of new technology	92	70.8	36	27.7	2	1.5	1.69
Market outlet	72	55.4	58	55.4	0	0.0	1.55
Price information	69	53.1	59	45.4	2	1.5	1.52
Accessible road	72	55.4	58	44.6	0	0.0	1.55
Good and motorable road	76	58.5	54	41.5	0	0.0	1.58
Good bags/sacks	97	74.6	33	25.4	0	0.0	1.75
Grand Mean							**1.48**

Source: Field survey, (2017).

CONCLUSION AND RECOMMENDATION

Soybean farmers in Niger State are predominantly individuals with low socioeconomic status characterized by no/low level of formal education, farming as primary livelihood activity with personal savings as the only source of financial capital for production. The study further concludes that the main benefit derived from soybean production was its direct contribution to improved standard of living and food supplement for children in households. Also, soybean production is challenged with a number of constraints, major ones were insufficient working capital and excessive rainfall. Major production needs of the farmers were herbicides, availability of good seeds and provision of fertilizer. We recommend that financial institutions should partner with farmers' cooperative society in providing capital for soybean farmers. Government and/or Non-Governmental Organization should subsidize agro inputs needed for soybean production. There is need for awareness and capacity building on climate smart agriculture among the soybean farmers in the study area to address the constraint of excessive rainfall.

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ADOPTION OF ENVIRONMENTALLY SUSTAINABLE PRACTICES IN RURAL ATACORA, BENIN

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ABSTRACT

Despite the importance of the Environmentally Sustainable Practices (ESPs) in safeguarding the environment while improving food security, ESPs adoption rates in rural areas a still low in developing nations like Benin Republic. Using primary data collected from 405 rural households, in three municipalities of the Northern Benin, multivariate probit and Poisson models were used to examine the factors influencing the adoption of multiple ESPs and ESPs adoption intensity respectively. The EPSs considered include: crop diversification, contour plowing, crop residue incorporation, composting, cover cropping, animal manure, animal traction, crop rotation. The results show that rural households' adoption of different ESPs and their intensity of utilization are significantly subjected various factors such as: gender of the household head, education, age, farm size, contact with extension agents as well as other households' wealth related status. With the Poisson regression model, the result shows that factors such as age of the household head, education, farming experience, livestock ownership, soil erosion menace and workshop attendance, significantly influence the intensity of multiple ESPs adoption. The study recommends that Government and various stakeholders should invest in both formal and informal trainings in order to encourage and facilitate the adoption of ESPs in the rural settings.

Key words: *Multivariate probit model, Environmentally Sustainable Practices, Poisson regression model, Benin.*

INTRODUCTION

In developing countries such as Benin Republic, the agricultural production remains one of the pivotal levers for development. It is a fundamental precondition for poverty eradication, inequality reduction, quality education as well as the attainment of sustainability of cities and communities. In order words agriculture significantly contribute to the Gross Development Product of the country, absorbing a huge labor force. The majority of the agricultural labor force is living in rural areas, facing some vulnerabilities, which need to be addressed for the purpose of attaining the Sustainable Developmental Goals (SDGs).

No doubt, increasing subsistence demands in the country is due to demographic growth and access to land for the amelioration of agricultural performance and food security. The historical background and land policy reforms related issues such as the modification of the property right since the independence in 1960, 1991, 2013 and 2017 as noted by Akowedaho et al. (2022), have led to complex situations negatively impacted by land accessibility in the country. In addition, smallholder farmers are facing agricultural product shocks due to climate change issues resulting in uncertainties in production with other related issues affecting their welfare. This situation therefore fragilizes sustainable food production while making rural households vulnerable to food in security in the country specifically in the northern parts of the country leading to soil degradation (Akowedaho et al., 2022).

In response to these issues, numerous environmentally sustainable practices have been developed and promoted by developmental agencies. Such disseminated interventions include soil conservation practices such as the adoption of animal manure, crop residue incorporation among others as the case has been documented in Ghana (Ehiakpor et al., 2021), in the Republic of Zambia (Arslan et al., 2014), in Nigeria (Olagunju et al., 2020) and in many other African countries. Notwithstanding the fact that the Government of Benin alongside donors are playing important roles in agricultural development, the country is yet to overcome land degradation, low soil fertility as well as climate change related issues, due to the low adoption rate of environmentally sustainable practices as the case has been noticed in other SSA countries by (Kagoya et al., 2018). Smallholder farmers on their field face specific realities that make them adopt multiple ESPs. In other words, adopting a certain ESP may be dependent on the usage of another adopted ESP. A well-known example is that of the soil management practices package which include minimum tillage and a balanced application of inputs (irrigation) (Oyetunde-Usman et al., 2021). Thus, the importance of monitoring the interdependence of multiple ESPs adoption for a comprehensive assessment of the drivers of ESPs adoption (Wu & Babcock, 1998).

Numerous studies have investigated on the factors that influence ESPs adoption in various parts of Africa such as Ethiopia (Bedeke et al., 2019), Ghana (Ehiakpor et al., 2021), Nigeria (Olagunju et al., 2020). An important conclusion from these studies is that technology adoption as emphasized by Oyetunde-Usman et al. (2021) is location-specific but also differs across households and various needs. These studies however emphasize and advocate on a thorough comprehension of farmers' acceptance tendencies in order to frame policies that could improve their inclination towards adoption. Danso-Abbeam et al. (2017), further emphasized on the need of studying adoption decision of multiple ESPs using MVP (multivariate probit) models being relatively scarce in the literature.

The aim of this study is to examine the factors that influence multiple ESPs adoption among farming households in Atacora Region, Benin Republic. This study makes significant contributions to the literature. It examines the linkages between the ESPs components using the MVP method. It further identifies the determinants of ESPs adoption using count data modelling. Given the fact entirety of the farming households cannot adopt all the ESPs due to various realities, this study focuses on two research questions: (a) Which factors influence adoption of multiple ESPs among farming households? (b) What factors influence ESPs adoption's intensity?

METHODOLOGY

The analysis employed the Multivariate Probit Model to unravel the intricate relationships between determinants impacting the adoption of various Environmental Sustainability Practices (ESPs). This model is designed to accommodate the effects of independent variables on multiple practices, all while addressing associations between both observable and latent error terms. The efficiency of the Multivariate Probit Model shines through its capability to unearth correlations that exist between unobservable and unmeasured factors within ESP adoption studies. This consideration is essential to avoid skewed and inefficient estimations that can arise from neglecting these crucial interdependencies.

Capturing Adoption Intensity through Count Data Models

The study's objective is to quantify the intensity of ESP practice adoption within the region, specifically focusing on the number of ESP practices implemented by rural households. Count data models, extensively used for this purpose, have been previously explored by pioneering researchers such as Greene (2008) and Trivedi (2013). These models concentrate on adoption intensity, utilizing techniques like the Poisson Regression model, which is tailored to situations where the dependent variable signifies the count of a particular event or behavior. The Poisson Regression model operates on the assumption of equi-dispersion, implying that the conditional mean and variance are statistically equivalent.

The Poisson Regression Model

The Poisson Regression Model proposed by Greene (1997) is represented as followed:

Pr(Y=y) =e- yy! , y = 0, 1, 2

The assumption here is that the parameter is to be log-linearly as relates to the regressors ($X_i, \ldots . X_n$)

ln ()=1xi

This leads to the log-likelihood function given by:

ln L =i=1,2, ...n [-i+yi1xi - lnyi!]

The following equation was then used to estimate the expected number of adopted practices by an ith individual.

E [yiIxi]=var [yiIxi] =exp [1xi +i]

Here, X = k*1 is a vector of independent variables, while β = k*1 is a vector of parameters. Thus the equation can be rewritten as:

E [Yi]=exp 1 X1i exp 2 X2i............ exp k xki=exp [iXjn] Ci

Here

j : [1, k] (can take a value from 1 to k)

Ci is a constant. Ci is the product of the outstanding exponential terms in equation 5.13

In the case of the dichotomous explanatory variable,

if, Xji=0,E[Y1]=Ci and when Xji=1,E[Y1]=BjCi

Therefore,

Hence, the expression 100 x (exp(βj) - 1) computes the percentage change in the expected value of Y when the variable xj transitions from zero to one, across all observations (i). In a broader context, for independent variables assuming multiple integer values, the incremental change in the expected adoption level of improved technologies, as xj shifts from xj1 to xj2, can be determined as:

dydx=exp jxj2- expjxji expjxji

In this research, improved adopted practices was modelled. The empirical model aims at examining the rural household's characteristics that influence their decision to adopt the improved adopted practices. The covariates are: age, gender, education, farming exp, household size, farm size, livestock, pests, constant erosion, flooding occurrence, contact ext. agents, dist. to-market, workshop, attendance, credit access.

RESULT AND DISCUSSIONS

Multivariate Probit model of the drivers of ESPs adoption

The Multivariate Probit model was employed to investigate on the main objective of this research which is to examine the drivers of multiple ESPs adoption in the study area. The results from the model presenting the coefficient estimates are presented in table 1. When considering household characteristics such as age of the household head, table 1 shows that the probability of adopting crop diversification, contour plowing, crop residues incorporation, cover cropping and animal manure, increases among young rural households. The implication here is that younger farming households have a higher chance of adopting these practices, due to capability of understanding and adopt the modern technologies coupled to other innovative practices in agriculture such as improved seeds varieties. This is partly in line with the findings of Oyetunde-Usman et al. (2020) who found that younger farmers were able to adopt improved crop production seeds and fertilizers in Nigeria. This however differs from the finding of Ehiakpor et al., (2021), who revealed that older farmers have a higher chance of adopting the sustainable practices due to the experience gained and long run benefit evaluation of such technologies in Ghana. Considering the case of gender of the household head, the statistics reveal that the male headed households were likely to adopt cover cropping while the probability of adopting animal manure increases among female headed households. This result suggests in a way that male farmers recognize the role of saving cost and reduce the need for synthetic fertilizers through cover cropping. On the other side, female farmers still lack behind with the adoption of innovative ESPs. Previous studies such Quisumbing & Pandolfelli (2010) found that the low adoption of these agricultural innovative approaches is due to various causes such as cultural acceptability, suitability in technology for the female gender agricultural chores, and the differences existing in technology preferences. The result further reveal that years of schooling have a positive and significant influence on specific ESPs such as crop diversification, crop residues incorporation, cover cropping, animal traction. This however have a negative effect on composting and crop rotation. This is quite reasonable due to the fact that crop diversification, crop residues incorporation, cover cropping, animal traction is more knowledge-based practices as compared to specific indigenous practices such as crop rotation. This corroborates the findings of Ehiakpor et al. (2021).

Further to this, farming experience was found to have a positive and significant relationship effect on crop diversification, contour plowing, crop residues incorporation, cover cropping and animal manure. This implies that experienced farmers are more likely to adopt these practices. This is probably due to the skill gained through frequent agricultural involvement. This corresponds to the study of (Kassie et al., 2015)

The analysis also indicates that farm size was positive and significant in driving the adoption of composting and animal traction. It has however a negative influence on the adoption of crop diversification, contour plowing, crop residues incorporation. This suggest that households with larger farm sizes are more likely to adopt composting and animal traction as compared to households with lesser farm sizes. This may be because larger farm size ownership allows for farming experience on different plots targeted at promoting soil conservation as well as production amelioration. This result is in line with past studies such as that of Danso-Abbeam et al. (2017) and Oyetunde-Usman et al. (2020). On this Ehiakpor et al. (2021), argue that low adoption of ESPs such as crop rotation on their farmland may be related to other related aspects such as poor land management and insecurity issues.

The result further indicates that livestock ownership was positive and significant in driving the adoption of cover cropping and animal manure. This is probably due to the fact that households with a considerable number of livestock benefit from the organic matter produced in the form of dung or manure. This subsequently serves at a natural fertilizer encouraging also the adoption of cover cropping for soil erosion menace prevention and soil enhancement purpose. This conforms with other scholarly works (Danso-Abbeam et al., 2017; Kassie et al., 2015a).

Concerning farmers perception, rural farmers who experience erosion menace on their production field were more likely to adopt crop diversification, cover cropping, animal traction crop residues incorporation on their plots. Unfortunately, those farmers experiencing soil erosion menace were less likely to adopt animal manure. This negative relationship may be due to specific logistical challenges generated by erosion menace such as the disrupted soil structure that can make manure application les effective. It consequently becomes difficult for the crop to retain and use the nutrients from the manure. On the other side, rural farmers who experience flooding have higher chances of applying cover cropping, animal manure composting but also adopt crop diversification and crop rotation on their plots. There is however a negative and significant relationship with contour plowing. A plausible explanation is that this could be attributed to flooding that can overwhelm the specific limitations made for contour plowing purpose. This is line with Kassie et al. (2015) and Oyetunde-Usman et al. (2021).

Considering the institutional variables, the coefficient of extension services positively impacts on the rural household adoption of crop residues incorporation, cover cropping and crop rotation. This shows that rural households consider extension agents' advice concerning sustainable land practices that can prevent agricultural production issues such as disease attack, pest among others. Surprisingly, extension services' coefficients of suggest that rural farming households are less likely in the case of the adoption of crop diversification and animal manure. This may be related to the resource constraint that extension agents face limiting thus their ability of providing constant educational support to rural farmers, constraining thus their willingness of crop diversification and use of manure. Further results reveal that distance to market was found to have a positive and significant relationship with the adoption of crop residues incorporation but a negative and significant relationship with the adoption of animal traction. Additionally, rural farming household with access to agricultural workshops influence their adoption of crop diversification (at $p < 0.05$), animal manure (at $p < 0.1$) and animal traction (at $p < 0.1$).

Credit accessibility of rural households is relevant when considering ESPs adoption. The result of the regression also shows that households who receive agricultural credits are more likely to adopt composting and animal manure on their plots. Credit accessibility however was found to have a negative and significant effect on the adoption of crop residues incorporation. This could be because crop residues incorporation may require additional cost coupled with the lack of sufficient knowledge and education about crop residues incorporation on agricultural plots.

Table 1: Multivariate Probit model of the drivers of ESPs adoption

Covariate	Crop diversification		Contour plowing		Crop residues Incorporation		Composting		Cover cropping		Animal Manure		Animal Traction		Crop rotation	
	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.
Age	-0.036*	0.01	-0.018***	0.009	-0.023**	0.010	0.002	0.010	-0.194***	0.011	-0.021***	0.012	-0.005	0.111	-0.012	0.012
Gender	-0.351	0.244	-0.150	0.231	-0.003	0.256	-0.349	0.245	0.924**	0.396	-0.611**	0.281	0.595	0.435	-0.481	0.395
Education	0.061*	0.015	0.011	0.014	0.049*	0.016	-0.041**	0.016	0.042*	0.016	0.014	0.018	0.043*	0.016	-0.034**	0.019
Farming Exp	0.026*	0.008	0.021*	0.007	0.029*	0.009	-0.001	0.008	0.029*	0.009	0.030*	0.009	-0.004	0.009	0.009	0.009
Household size	-0.011	0.016	0.013	0.016	0.018	0.017	0.023	0.016	-0.024	0.018	-0.016	0.020	-0.026	0.019	0.010	0.021
Farm Size	-0.129***	0.074	-0.112**	0.045	-0.336*	0.107	0.139*	0.043	0.042	0.081	0.046	0.049	0.113*	0.045	0.018	0.080
Livestock	0.003	0.002	0.001	0.002	0.004	0.002	0.003	0.002	0.005**	0.002	0.007*	0.003	0.002	0.002	-0.001	0.003
Pests	-0.404	0.269	0.406	0.268	-0.093	0.284	0.135	0.277	0.232	0.379	0.237	0.309	0.214	0.424	-0.010	0.333
erosion menace	0.612*	0.239	0.339	0.226	0.675*	0.264	-0.161	0.232	0.856**	0.356	-0.805*	0.254	0.679**	0.356	0.295	0.292
Flooding occurrence	0.442***	0.247	-0.536**	0.240	-0.088	0.256	0.911*	0.312	0.605***	0.356	0.753**	0.330	0.197	0.343	0.492***	0.300
Contact ext. agents	-0.341**	0.168	-0.056	0.163	0.361**	0.180	0.060	0.174	0.393**	0.185	-1.023*	0.216	0.048	0.190	0.598**	0.249
Dist. to-Market	0.009	0.010	0.015	0.011	0.042*	0.011	-0.001	0.011	-0.008	0.012	0.003	0.013	-0.043*	0.017	-0.009	0.014
Worksho	0.421*	0.17	0.260	0.17	-0.089	0.19	-0.234	0.19	0.262	0.18	0.482*	0.216	0.507*	0.196	-0.069	0.26

p Attendance	*	8		5		1		2		7						6
Credit access	-0.091	0.208	0.140	0.202	-0.557**	0.239	0.426**	0.206	-0.077	0.217	1.106*	0.230	0.202	0.223	0.285	0.340
Cons	0.181	0.418	-0.351	0.411	-1.35*	0.469	-1.568*	-0.498	-3.724*	0.670	-0.572	0.507	-2.302*	0.649	1.280**	0.563

10*, ** 5 and *** 1 denote significance levels at, and percent respectively.

Source: Data analysis (2024)

CONCLUSION AND POLICY IMPLICATIONS

The imperative roles of ESPs in boosting agricultural productivity, reducing poverty while securing and preserving the environment for both present and future generations have been well described in the literature. In spite of these advantages alongside awareness on these technologies, adoption still remains low in rural areas of the Sub-Saharan African countries. Using primary data collected in the Atacora Region, Benin, the study examined the environmental sustainability practices adopted by farm households and the intensity of adoption in the region. The study adopted multivariate probit and Poisson regression models. The ESPs considered for this study were: crop diversification, composting, contour plowing, crop residue incorporation, cover cropping, animal manure, crop rotation and animal traction. The results showed that it exists some complementarity among animal traction - cover cropping contour plowing - crop residue incorporation crop diversification- animal manure, while there is also some substitutability among crop diversification- composting crop residue incorporation-animal traction and cover cropping- crop rotation. The study revealed that farming households adopted different ESPs and their intensity of adoption depends on various characteristics such as gender of the household head, age, education farm size contact with extension agents as well as other households' wealth related status. Furthermore, factors affecting intensity include: age of the household head, education, farming experience, livestock ownership, soil erosion menace occurrence and workshop attendance.

Based on the results obtained from this study a number of vital implications can be presented. It can be concluded from our findings that ESPs are in a way interdependent. This should thus be considered prior to and while designing environmentally sustainable policies. Since multiple factors influence the combination of ESPs, it is paramount that policymakers should consider socioeconomic factors, farmers perceptions as well as institutional factors to ensure maximization of the benefits that ESPs procure to the adopters and to the environment at large. The government should therefore strengthen extension agents at providing educational support through workshops and field demonstrations as to increase their understanding and adoption of ESPs in the country and specifically in the Atacora region.

CHAMPIONING SUSTAINABLE WILDLIFE MANAGEMENT THROUGH STUDENT ADVOCACY AT T.A AFOLAYAN WILDLIFE PARK, NIGERIA

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ABSTRACT

Advocacy is an essential act that should be encouraged amongst all stakeholders involved in biodiversity management. This study thus assessed the level of advocacy for sustainable management of T. A. Afolayan Wildlife Sanctuary among students of wildlife management in FUTA. A well-structured questionnaire was administered to 368 participants who were all students of Wildlife Management, FUTA and data was analyzed using Statistical Package for Social Sciences version 21. The result was presented descriptively using tables and charts while inferential statistics involved the use of analysis of variance. The modal age category was 18-25 years (82.8%). Most of the participants were female (66.9%) and single (95.4%). Results revealed that the participants perceived that there is a need for more scientific methods of wildlife conservation and that biodiversity would be effectively conserved if we exhibit positive attitude towards sustainability such as proper waste management among others. Also, findings revealed that the participants exhibits positive attitude towards advocacy shown by their willingness to educate others on the importance of sustainable wildlife management and they were also willing to financially support organizations that address conservation issues. The study recommends intensification of environmental awareness, ecotourism advocacy and promotion of programs that will encourage advocacy for sustainable biodiversity management.

Key words: *Advocacy, Biodiversity, Sustainability, Willingness, Waste Management.*

INTRODUCTION

Wildlife is very important in maintaining ecological balance of the ecosystem while also providing economic development due to its regenerative natural value (Weisenborn, 2018). Wildlife management can be described as effectively managing biodiversity resources in order to prevent extinction of these resources and protect their habitats alongside (Sandhyarani, 2018). Wildlife management describes the management of biodiversity together with their habitat and human beings who have various associations with fauna, flora and other resources in the ecosystem (Kadykalo et al., 2021). This indicates that there is need to infuse aspects of dimensions of human beings such as wildlife advocacy actions with management activities (Decker et al., 2012).

There is possibility of another occurrence of mass extinction of wildlife due to the massive decline of wildlife resources over the years (Ceballos et al., 2015). Biodiversity loss is a very devastating problem that poses crucial effects on the welfare of humanity as well as sustainability of biodiversity (Karanth et al., 2012). Although the major reason for this biodiversity decline is attributed to human activity, there is still need for increased conservation efforts so as to prevent further biodiversity loss as well as the loss of ecosystem services (Ceballos et al., 2015). Ex-situ conservation sites can help enhance ecosystem and biodiversity conservation initiatives due to the huge number of tourists' influx in these sites worldwide (Grajaj et al., 2017). These conservation sites provide experiences and avenue for the delivery of conservation education that can influence tourists' behavior to engage in environmentally-friendly habits and advocacy (Dustan et al., 2016).

Natural resources cannot communicate in an understandable language so their conservation relies on people's advocacy (Wardell-Johnson et al., 2019). Advocacy for sustainable wildlife management has emerged as one very aspect of research in many studies due to its importance in maintaining smooth running of the ecosystem, preventing waste or pollution and ensuring sustainability of the environment (Recher, 2019). Wilson et al. (2010) clamored for increased and engaging supportive efforts from all stakeholders involved in wildlife management. Also, in order to ensure effective support and advocacy for social and economic needs of human beings, Girard (2014) underscored the significance of engaging in practices and strategies that are targeted at sustainable management of wildlife resources.

Research has recognized that there is need for increasing public support and advocacy for conservation (Miao et al., 2021). It is critical to have an understanding about public support for natural resources which is associated with social and ecological benefits (Bennett et al., 2019). However, there has been dearth of information on advocacy for sustainable wildlife management especially from the lens of students who are knowledgeable about wildlife conservation. This study aims to fill this knowledge gap by assessing the level of advocacy for sustainable wildlife management among students. This study also aimed to determine the students' perception of sustainable wildlife management as well as the willingness of the students to advocate for sustainable wildlife management.

METHODOLOGY

This study was carried out in Federal University of Technology Akure located between Latitudes 7.2935^{o}Nand 7.29263^{o}N and Longitudes 5.1425^{o}E and 5.1445^{o}E. The study made use of well-structured questionnaire, directed at three hundred and sixty-eight (368) students of Ecotourism and Wildlife Management who had visited the T.A Afolayan Wildlife Sanctuary. The questionnaire construct was designed to assess the level of advocacy for sustainable wildlife management. The sampling was done purposively and data was analyzed using Statistical Package for Social Sciences (Version 21.0). The result was presented descriptively using tables while inferential statistics involved the use of analysis of variance.

RESULTS

Socio-Demographic Characteristics

Table 1 reveals the socio-demographic characteristics of the respondents. Highest percentages of the respondents were in the age group 18-25 years (82.8%), females (66.9%) and singles (95.4%). Also, all the respondents were Nigerians (100%). Highest percentages of the respondents were Christians (89.1%). Furthermore, highest percentages of the respondents were in 500 level (40.2%). Highest percentage of the respondents had visited the site more than three times (99.8%).

Table 1: Socio-demographic characteristics of respondents

Variables	**Frequency (N=368)**	**Percentage (%)**
Age		
18-25 years	305	82.8
26-30 years	62	16.8
31-40 years	1	0.4
Gender		
Male	122	33.1
Female	246	66.9
Marital status		
Single	351	95.4
Married	17	4.6
Nationality		
Nationality	368	100.0
Religion		
Christianity	328	89.1
Islam	40	10.9
Educational level		
200 level	62	16.9
300 level	80	21.7
400 level	78	21.2
500 level	148	40.2
Visit frequency		
Thrice	1	0.2
More than three times	367	99.8

Perception of students about sustainable wildlife management in T.A. Afolayan Wildlife Park

Table 2 reveals the perception of students about sustainable wildlife management. The mean score ranged from 4.21 to 4.76. "We need more scientific methods for wildlife conservation" had the highest mean value of 4.76 while "Advocating animal rights is more important than human utilization of wildlife" had the lowest mean value of 4.21.

Table 2: Perception of students about sustainable wildlife management in T.A. Afolayan Wildlife Park

Factors	**Mean**	**St. D**
We need more scientific methods for wildlife conservation	4.76	0. 456
Wildlife can be effectively conserved as long as they are given care and love	4.73	0.522
Animals should have equal rights with humans in welfarism	4.34	0.858
As long as the abuse of wildlife and their products is prohibited; wildlife can be conserved	4.57	0.792
Advocating animal rights is more important than human utilization of wildlife	4.21	1.003
Wildlife would be effectively conserved if we exhibit positive attitude towards sustainability such as waste management and so on.	4.60	0.657
Licensed hunting opportunities should be provided	4.38	0.946
Benefits of wildlife and its resources surpasses its illegal usage	4.43	0.806
T.A. Afolayan Wildlife Park provides practical knowledge of theories taught in class	4.24	0.931
Visiting T.A. Afolayan Wildlife Park influences the need/desire to conserve and advocate for the conservation of wildlife resources	4.35	0.791

Keys: SA- Strongly Agree, A-Agree, U-Undecided, D-Disagree, SD-Strongly Disagree

Advocacy for sustainable wildlife management

Table 3 reveals the students' advocacy for sustainable wildlife management. The mean score ranged from 4.38 to 4.67. "I am willing to educate others about the importance of Sustainable Wildlife Management" had a mean value of 4.67 while "I am willing to financially support organizations that address conservation issues" had the lowest mean value of 4.38. Table 3 also reveals that there is a significant difference in the students' advocacy for sustainable wildlife management at the park ($p<0.01$).

Table 3: Advocacy for sustainable wildlife management

Factors	**Mean**	**St. D**	**f value**	**P-value**
I am willing to educate others about the importance of Sustainable Wildlife Management	4.67	0.562	9.124	0.000
I am willing to engage in volunteer activities for wildlife or nature events in the Park and the outside World	4.52	0.672	13.543	0.000
I am willing to financially support organizations that address conservation issues.	4.38	0.776	9.446	0.000
I am willing to behave in an environmental-conscious manner	4.56	0.632	15.549	0.000
I am willing to pay to visit the Park to enhance its development	4.56	0.694	6.452	0.000
I am willing to tell others about the existence of T.A. Afolayan Wildlife Park	4.55	0.682	8.062	0.000

Keys: SA- Strongly Agree, A-Agree, U-Undecided, D-Disagree, SD-Strongly Disagree

DISCUSSION

Socio-demographic characteristics of the respondents who have visited the wildlife sanctuary were within youthful age group which is similar to findings by Arowosafe et al. (2022). The study respondents revealed more females than males, contradictory to findings by Tunde-Ajayi (2021) who revealed majority of their findings to be males. Also, most of the respondents were singles as supported by Abidakun and Tunde-Ajayi (2021). The respondents also visit the wildlife sanctuary regularly, indicating that they are familiar with wildlife management and what it entails. The respondents were asked about their perception about sustainable wildlife management and they opined that there is need for more scientific methods for wildlife conservation. They also claimed that wildlife can be effectively conserved if they are cared for and they stated that effective conservation of wildlife can be achieved if there is exhibition of positive attitude towards sustainability such as waste management and other strategies as supported by Meadows (2011) and Fabian et al. (2020) who claimed that effective wildlife conservation can be attained through exhibiting positive attitude towards sustainability.

The respondents further showed advocacy for sustainable wildlife management by stating that they are willing to educate others about the importance of Sustainable Wildlife Management indicating the importance of spreading sustainable wildlife management messages as supported by Ballantyne et al. (2009). They also stated that they are willing to behave in an environmental-conscious manner in their support for sustainable wildlife management advocacy as supported by Amoo et al. (2022) who underscored the importance of conservation areas to gain support and positive attitude of people towards conservation.

CONCLUSION

This study concludes the respondents expressed a strong belief in the importance of sustainable wildlife management, emphasizing the need for more scientific approaches in conservation efforts. Their perceptions underscore the importance of exhibiting positive attitudes towards sustainability practices, such as waste management, in effectively conserving wildlife. Furthermore, their willingness to educate others and adopt environmentally conscious behaviors highlights their potential in advocating for sustainable wildlife management. This study emphasizes the need to garner positive attitudes and advocacy from the public in order to achieve successful wildlife conservation outcomes.

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ASSESSING DIETARY PATTERNS OF POULTRY PRODUCTS AMONG URBAN POULTRY-FARMING HOUSEHOLDS IN UMUAHIA NORTH LOCAL GOVERNMENT AREA OF ABIA STATE, NIGERIA

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ABSTRACT

The study assessed the dietary patterns of poultry products (meat and eggs) among urban poultry-farming households in Umuahia North Local Government Area of Abia State, Nigeria. The specific objectives of the study were to delineate the socio-demographic characteristics of the urban poultry-farming households, their dietary consumption patterns in poultry products including frequency of consumption of poultry products, determination of monthly expenditure on poultry products and constraints experienced by urban poultry-farming households in the study area. Snowballed sampling technique was used to randomly select ninety urban poultry-farming households from a population of 324,900 in Ndume Ibeku, Amuzukwu Ibeku, Osah Ibeku, Umuagu Ibeku and Afara Ibeku Autonomous Communities, which make up the urban areas of the local government area. A structured questionnaire with close-ended questions was used to collect data for the study and were analyzed using descriptive statistics. The analyzed results indicated a mean age of 41.3 years, percentage majority of the respondents being females (66%), 77.33% were married, 35.18% had secondary education, 40.56% engaged in poultry farming as a primary occupation, 48.88% had an average of 15years experience in poultry farming, 48.88% earned above N100,000.00 annually from poultry farming and have an average family size of 5 persons. Majority of the respondents occasionally consumed boiled chicken meat and egg followed by fried chicken meat and egg, and scarcely consumed grilled chicken meat (from chicken either still on medication or dead chicken). The mean monthly expenditure on chicken products was N4,999.00 while some of the major constraints limiting consumption of chicken products include high cost of retail price of poultry products, low financial status of respondents, limited access to chicken and egg, lack of storage facilities, long distance to market/farm and dietary restrictions. It was recommended that urban poultry-farming households should be assisted with credit facilities, improved and adaptable species of day-old chicks, well informed on the nutritional benefits of regular consumption of poultry products and the health risks of consuming sick or dead chicken meat; and ensure efficient production of safe chicken products.

Target audience: Poultry Farmers, Animal Scientists, Home Economists, Policy Makers and Researchers

Key words: *Dietary Patterns, Poultry products, urban poultry farming, Abia State.*

INTRODUCTION

In recent times, animal products including poultry meat and egg have been available to a limited extent in developing countries and to a fuller extent in developed countries of the world. Over 1.02 billion people globally have been estimated to suffer malnutrition due to protein deficiency (FAO, 2009). Although responsible protein consumption is being highlighted globally, it is pertinent to note that over 900 million people are protein-deficient and out of which about 800 million are estimated to be from the developing countries of the world as observed by Abdullahi and Aubert (2004). Relying on the estimated 70g of protein per meal per person with about 35g supposedly coming from animal sources and that only about 7g of animal protein is being consumed (representing only 20 per cent of the daily protein requirements) by the FAO (2003), the Federal Government of Nigeria through various initiatives has continued to focus on the development and improvement of poultry industry due to its tremendous contribution to individual protein intake and serving as a ready source of income to smallholder farmers (Afolabi, 2002). The implication of these initiatives is to boost animal protein production, availability and accessibility as the present demand for animal protein in Nigeria and other developing countries of the world is far from being met.

Chicken meat and egg production constitutes an important component of the agricultural economy in developing countries and also constitutes an instrument of socioeconomic change, improved income and quality of rural life in Nigeria (Olaniyi, *et al*., 2010). Poultry farming as an aspect of livestock production is important to the biological needs, economic and social development of the people in any nation (Oladeebo and Ambe-Lamidi, 2007). However, consumption of these poultry products determines the protein deficiency of poultry-farming households. Ayoola (2015) notes that protein deficiency is evident in Nigeria's annual egg consumption, standing at 70 eggs per person, in contrast to developed nation like China with 370 eggs per person. Closing this protein consumption disparity appears challenging, given the existing financial and technological constraints experienced by poultry farming households. Poultry farming household's protein consumption need to be efficient. To this effect, the household protein insecurity can be overcome by strengthening the household's poultry (chicken meat and egg) consumption patterns. This forms the basis of this research with the specific objectives to;

i. identify the socio-demographic characteristics of the poultry-farming households in the study area,
ii. assess the frequency of consumption of chicken meat and egg among poultry-farming households in the study area,

iii. determine the monthly expenditure of chicken meat and egg among the poultry-farming households in the study area and
iv. identify the constraints to the consumption of chicken meat and egg in the study area.

METHODOLOGY

Study design: The study adopted a descriptive survey research design. The survey research design was considered appropriate as it elicits information from the respondents concerning their dietary patterns of poultry products (chicken meat and egg).

Area of the study: The study area was Umuahia North Local Government Area of Abia State, occupying an area of 245km^2 and a population of 220,660 according to National Population Commission 2006 census (NPC, 2006). It is located within South-East agro-ecological zone of Nigeria, with a typical tropical humid climatic condition. The annual rainfall ranges from 2000-2,500mm, average annual temperature is 27^{0}C and the relative humidity ranges between 80-90^{o}C in the wet season (National Root Crop Research Institute- NRCRI, 2023). The area lies between 5^{o}30' and 5^{o}40' North of equator and longitude 7^{o}25' and 7^{o}32' East of Greenwich meridian.

Population for the study: The population of the study is randomly selected poultry farming households within the urban areas of Umuahia North L.G.A. of Abia State.

Sample selection procedure: 90 poultry-farming households were selected from the urban areas within the study area. Snowball sampling technique was used to select the respondents. In this method, one identified poultry-farming household referred the researchers to another poultry-farming household.

Instrument for data collection: The instrument for data collection was a set of questionnaire. The questionnaire was made up of four sections. Section A contained items on the demographic characteristics of the respondents. Section B elicited information on the frequency of consumption of chicken meat and egg among poultry-farming households. This was measured by using a 7-point Hedonic measurement scale weighted as follows: Daily, 5-6 days/week (6), 3-4 days/week (5), 1-2 days/week (4), once in a week (3), during festivities (2) and not at all (1). Section C obtained data on the monthly expenditure of the respondents on chicken meat and egg in the study area while section D elicited information on the constraints to consumption of chicken meat and egg in the study area. This was done by using a 3-point Likert rating scale of Very High Extent (3), High Extent (2) and Very Low Extent (1).

Validation of the instrument: The face validation of the instrument was established by three experts from the Department of Agricultural Education, Federal College of Education, Eha-Amufu, Enugu State, Nigeria.

Reliability of the instrument: Reliability of the questionnaire was established using Cronbach alpha method and reliability coefficient of 0.78 was obtained, showing high consistency of the test items.

Method of data collection: The respondents were visited in their homes and in their farms to obtain the information. 90 copies of the questionnaire were administered to the farmers verbally with the help of two trained research assistants. Any member of the household who could give reliable information was used for the study. Their responses were then ticked in the questionnaire accordingly. All the 90 (100%) copies of the questionnaire were correctly filled out and returned.

Informed consent: A verbal consent was obtained from the respondents before the study commenced. The purpose of the study, the voluntary nature of participation and confidentially of data were duly explained to them, after which they gave their consent.

Data and statistical analysis: Descriptive statistics such as frequency, percentage and means were used to analyze data. As reported by Madukwe *et al*., (2000) and Ekwe (2019), the recorded frequencies were multiplied by each Hedonic weight and divided by the pooled response. A class mark of 2.33 was established by dividing the maximum response value (7) by the 3 categories to obtain the following categories: 0.00-2.33 (scarcely consumed), 2.34-4.67 (occasionally consumed) and 4.67-7.0 (frequently consumed). Also, a benchmark of 2.0 was used as the cut-off point to determine the constraints to consumption of chicken meat and egg. The scored responses were first multiplied by each Likert weight and divided by the response pooled together. Problems above the cut-off point were considered a major problem and accepted while cut-off scores below 2.0 were considered minor and rejected.

RESULTS

Socio-demographic Characteristics of urban poultry-farming households in Umuahia North L.G.A. of Abia State

Table 1 shows the socio-demographic characteristics of the respondents. The results showed that 42% of the respondents were between 31-40 years of age, and 33.33% were within the age group of 41-50 years. It also showed that 73.33% of the respondents were married, 35.18% of them had post-secondary education, and 40.56% of them were full time farmers. The mean household sizes of the respondents were seven persons/household while the mean annually estimated income of the respondents gave a mean yearly income of N98,200.00.

Table 1: Descriptive statistics of the demographic characteristics of the respondents

Variables Frequency (n=90)	**Percentage (%)**	**Age**
20-30	16	17.78
31-40	30	33.33
41-50	38	42.22
51-60	6	6.67
Marital status		
Single	13	14.44
Married	66	73.33
Divorced	6	6.67
Widowed	5	5.56
Sex		
Male	33	34.0
Female	57	66.0
Level of education		
Informal	10.0	12.01
Primary	22.0	24.13
Secondary	32.0	35.18
Post-secondary	26.0	28.68
Primary occupation		
Farming	37.0	40.56
Civil servants	22.0	24.67
Traders/business/artisans	29.0	32.44
Others	2.0	2.33
Household size		
1-3	27.0	30.01
4-6	44.0	48.88
7 and above	19.0	21.11
Years of experience in poultry farming		
Less than 10 years	27.0	30.01
10-39 years	44.0	48.88
40 and above	19.0	21.11
Estimated annual income from poultry farming (N)		
Less than 50,000.00	19.0	21.01
51,000.00-100,000.00	27.0	30.01
Above 100,000.00	44.0	48.88

Source: Field Survey, 2024

Frequency of consumption of poultry products (chicken meat and egg) among urban poultry-farming households in Umuahia North L.G.A of Abia State

Table 2 shows the frequency of consumption of poultry products among the respondents. The results show that chicken meat is consumed mostly in the forms of fried: x=5.10, boiled: x=4.87, grilled: x=3.68.

Table 2: Distribution of respondents according to the frequency of consumption of chicken meat and egg

Frequency of consumption	Fried (Chicken meat & egg)	Grilled Chicken meat (Either still on medication or dead)	Boiled (Chicken & egg)
Daily (7)	4	0	11
4 days/weeks (6)	10	11	17
Thrice a week (5)	15	5	13
Twice a week (4)	17	4	10
Once in 2 weeks (3)	36	19	11
During festivities/ceremonies only (2)	10	47	29
Never (1)	0	4	0
Mean Max = 7	2.34	1.62	2.47
Remarks	Occasionally Consumed	Scarcely Consumed	Frequently Consumed

Key: 1-2.33 (Scarcely consumed), 2.34-4.66 (Occasionally consumed), and 4.67-7 (Frequently consumed)

Source: Field Survey, 2024

Monthly expenditure on poultry products (chicken meat and egg) consumption in the study area

The distribution of the respondents according to their monthly expenditure on chicken meat and egg consumption in the study area is presented in Table 3. The result shows that most (48%) of the respondents spend between N4000.00-N5,999.00 monthly on the consumption of chicken meat and egg. The mean monthly expenditure on chicken meat and egg by the respondents is N5,250.00

Table 3: Distribution of respondents according to their monthly expenditure on chicken meat and egg in the study area

Monthly expenditure range (N)	Frequency	Percentage
≤ 2,000.00	14	15
2,000.00-3,999.00	17	19
4,000.00-5,999.00	43	48
6,000.00-7,999.00	8	9
8,000.00-9,999.00	5	6
10,000.00- Above	3	3
Total	**90**	**100**
Mean	**N5,250.00**	

Source: Field Survey, 2024

Constraints to chicken meat and egg consumption in the study area

Table 4 presents major constraints to the consumption of chicken meat and egg in the study area. The respondents all agreed that the constraints identified were serious with mean scores of cost per kg and per crate.

Table 4: Constraints to chicken meat and egg consumption in the study area

Constraints	Very High Extent	High Extent	Very Low Extent	Total	Mean Score
High cost price per kg and per crate	59	22	10	231	2.53
Limited access to chicken and egg	44	28	18	211	2.34
Lack of storage facilities	36	34	23	199	2.14
Long distances to market/farms	37	44	9	208	2.31
Health concerns	25	19	46	159	1.77
Financial status	49	28	13	216	2.40
Dietary restrictions	46	31	13	213	2.37
Age	22	20	47	153	1.71

Source: Field Survey, 2024

DISCUSSION

The findings of this study regarding higher proportion of the respondents being female (66%) agrees with the report by Babayemi *et al*., (2017) who reported that women are more likely to engage in poultry production mostly at small scale level. Also, the respondents being mostly(42%) middle aged (41-50years) adults who are also mostly married (73.33%) show that the poultry-farming households within the urban areas of Umuahia North L.G.A. of Abia State engage in poultry enterprise as a means of livelihood and to provide family food security as reported by Ekwe (2019) and Ozor *et al*., (2015). The moderate family size (4-6) indicated a a useful source of labour for the poultry faming activities while the study showed that most of the respondents (35.18%) had up to secondary level of education which is an indication of good literacy level that can enhance chicken meat and egg consumption. Juxtaposing the number of respondents whose primary occupation is farming (40%) and their annual estimated income from poultry farming in the present prevailing high-inflationary economic realities in the present day Nigeria, the low income level of the respondents affected their dietary pattern relating to chicken and egg as reported by Ekwe (2019).

There was generally occasional consumption of chicken meat and egg mostly due to the major constraints identified in the study area while the form of chicken meat and egg consumed by the respondents was the boiled form followed by the fried form and scarcely by the grilled form, mostly from chicken either still on medication or dead chicken on medication, as observed from personal enquiry. This could be attributed to ease of convenience during preparation for boiling and frying either in a family kitchen or in the farm ad safety concerns on poultry zoonotic diseases. The study also indicated that most of the respondents (48%) spent on a monthly basis an average of N4,999.00 in the consumption of chicken meat and egg. This implies that the respondents did not spend much on consumption of chicken meat and egg. Among the constraints identified in the study area, health concerns and age did not matter while for example, the high cost price per kg and per crate as a major constraints are similar with the findings of Carlos (2017) and Akerele *et al*., (2015).

CONCLUSION AND RECOMMENDATION

It is concluded that poultry-farming households occasionally consumed chicken meat and egg as they are constrained by some major factors which limit them in having access to animal protein security within the urban areas of Umuahia North L.G.A. of Abia State. It was recommended that urban poultry-farming households should be assisted with credit facilities, improved and adaptable species of day-old chicks, well informed on the nutritional benefits of regular consumption of poultry products and the health risks of consuming sick or dead chicken meat; and ensure efficient production of safe chicken products.

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ASSESSING RAINFALL TRENDS AND IMPLICATIONS FOR WASTE MANAGEMENT IN SOUTH-WEST NIGERIA

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ABSTRACT

Global climate change has profoundly altered precipitation patterns, necessitating thorough regional assessments. This study investigates mean annual rainfall trends in selected cities of the geographical south-west Nigeria (Ikeja, Ibadan, Ilorin), situated in distinct ecological zones (Freshwater swamp forest, Lowland Rainforest, Southern Guinea Savannah), from 1960 to 2023. Secondary dataset of monthly rainfall sourced from the Nigerian Meteorological Agency, Abuja, were processed to compute mean annual values and graphed, with trend lines derived through second-order polynomial fitting. Bivariate linear regression analysis (BLRA), coupled with the F-test, assessed statistical significance. Preliminary findings show rainfall declined in the selected cities from around 1960 to the mid to late 1980s, then increased into the twenty-first century. The BLRA indicate that the initial downward trend was significant at 95% confidence only in Ikeja (correlation -0.52), while the subsequent upward trend was significant only in Ilorin (correlation 0.30). The increasing trend of rainfall as observed in this study bears significant implications for sustainable waste management. Increased rainfall heightens the likelihood of waste runoff and water pollution, posing environmental and public health risks. Moreover, the potential overflow of landfills aggravates environmental degradation. Revisiting policy approaches to Sustainable Development Goal (SDG) 12, which emphasizes responsible consumption and production alongside environmentally sound waste management, is imperative. Prioritizing resource efficiency, circular economy principles, and integrating climate resilience into waste management strategies are essential measures. Engaging communities in waste reduction initiatives fosters responsibility and ownership, particularly during periods of heavy rainfall, mitigating pollution risks effectively. Sustaining positive impacts and minimizing trade-offs necessitates maintaining policy coherence across sustainable development agendas. These findings underscore the urgent need for proactive and adaptive measures in waste management policies to address the evolving challenges posed by changing rainfall patterns in south-west Nigeria.

Key words: *Climate change, Rainfall trends, Waste management, Policy coherence, Sustainable development, Nigeria*

INTRODUCTION

Climate change is a complex worldwide phenomenon with vast consequences (Intergovernmental Panel on Climate Change (IPCC), 2023). One of its most notable effects is on precipitation patterns, as evidenced by observed changes in rainfall regimes globally. This has a substantial impact on a number of sectors, including waste management, water resources, and agriculture (Ibrahim et al., 2018; Ogunrinde et al., 2019; Al-Muhyi, 2022; Sharma & Priya, 2023). These changes are becoming more noticeable in Nigeria, as they are in many other places, and they may have an impact on how municipal solid waste is managed (Hammed & Sridhar, 2019; 2020; Ajaero et al., 2023).

The "geographical" South-west of Nigeria, consisting of cities like Ikeja, Ibadan, and Ilorin, is unique because of its dynamics of urbanization and its variety of ecological zones. Comprehending these geographic variations is essential for designing effective and lasting adaptation measures, alongside strategies for alleviating concomitant hazards and augmenting robustness across various sectors. Rainfall fluctuations are especially detrimental to waste management, which is essential to the health of cities and the environment (Hammed & Sridhar, 2019; Ogunbode & Ifabiyi, 2019; Ajaero et al., 2023). Thus, this study examines the annual rainfall trends in south-west Nigeria and analyses how it can affect sustainable waste management practices.

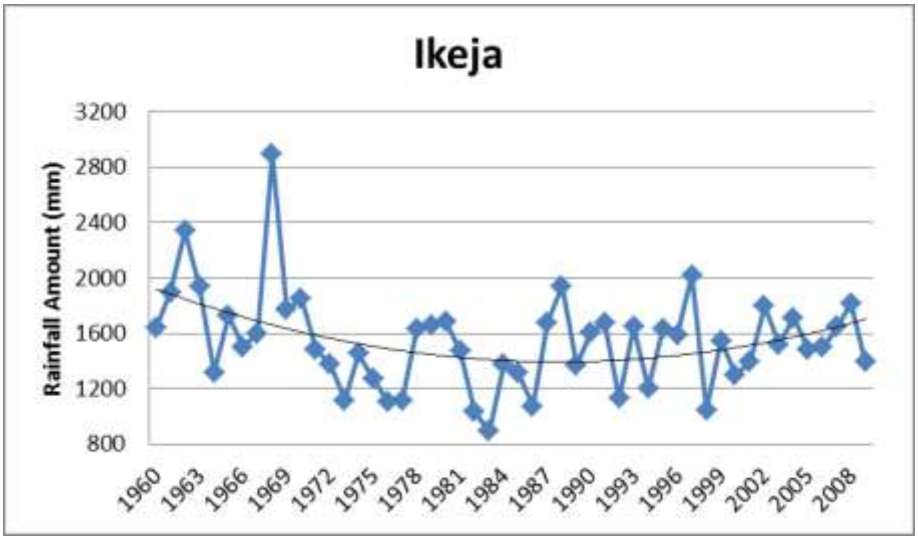
METHODOLOGY

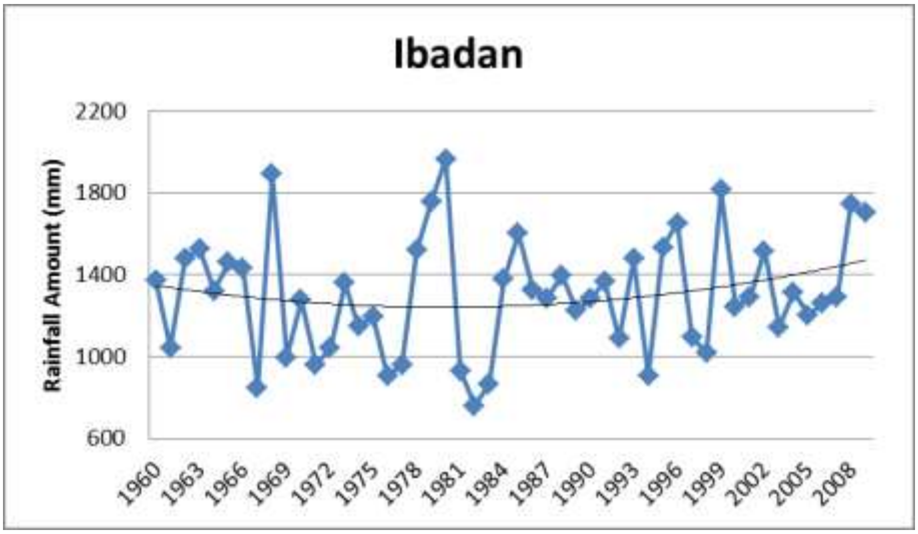
Secondary data for the years 1960–2023 from the Nigerian Meteorological Agency in Abuja were required for this study. They are monthly rainfall values collected for Ikeja, Ibadan, and Ilorin, three cities in the "geographical" south-west of Nigeria. Using the monthly data, mean annual rainfall values were computed and then plotted as graphs. According to Chukwudum and Nadarajah (2021) and Rifada et al. (2023), trend analysis was carried out via second-order polynomial fitting to determine temporal patterns in rainfall. To assess the statistical significance of trends, bivariate linear regression analysis (BLRA) in conjunction with the F-test was utilized (Lawal et al., 2022; Rifada et al., 2023).

RESULTS AND DISCUSSION

Preliminary findings (involving 1960-2009 data) indicate that rainfall declined initially from 1960 to about 1983-1984 in Ibadan representing the Lowland Rainforest; and 1987-1988 in Ikeja and Ilorin representing the Freshwater swamp forest and Southern Guinea Savannah ecological zones, respectively. From the initial downward tendency though, the trend later became upward from 1983-1984 in Ibadan; and 1987-1988 in Ikeja and Ilorin, up to 2009 (Figure 1). The downward and upward trends observed were in addition subjected to BLRA in order to determine their statistical significance, with rainfall being the dependent variable while time was used as the explanatory variable (Table 1). The output show statistically significant negative downward trend at the 95% confidence level in Ikeja with the correlation value of -0.52; on the other hand, the trend remained not statistically significant in Ibadan and Ilorin, with the negative correlation values of -0.2 and -0.19. The results also show that the upward trend detected was statistically significant at the 95% level of confidence in Ilorin with a correlation value of 0.30. For Ikeja and Ibadan however, the upward trend was not statistically significant with weak correlation values of -0.02 and 0.23, respectively.

The latter increasing trend in rainfall extending into the twenty-first century as observed in this study though it was only statistically significant in Ilorin appears to validate the climate change projections of the Ministry of Environment of the Federal Republic of Nigeria (2003), Adejuwon (2006), and the findings of Balogun et al. (2009), also Adepitan et al. (2017).





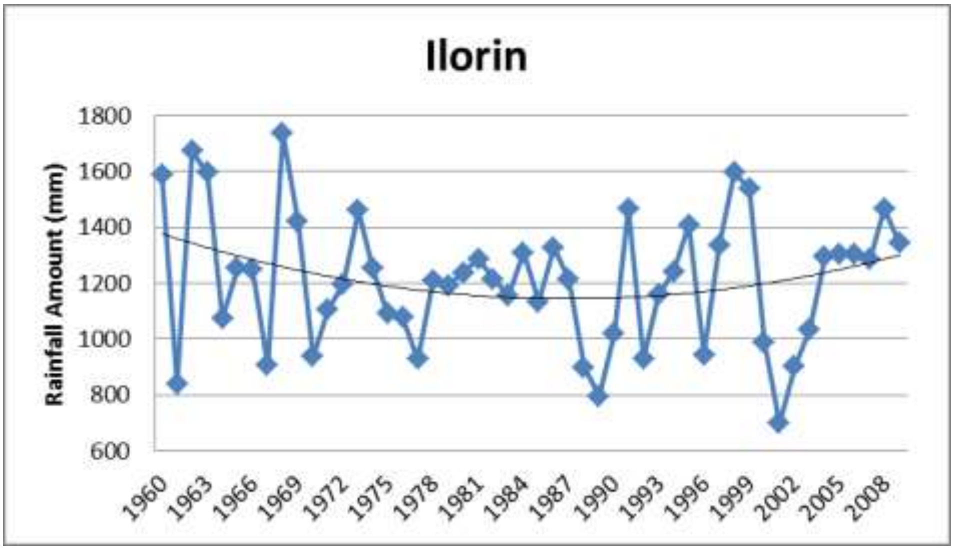


Figure 1: Annual rainfall trends in south-west Nigeria, 1960-2009. Blue lines depict annual values while black curves indicate polynomial trend lines.

Table 1: The BLRA outputs of the trends in annual rainfall in selected cities of the geographical south-western Nigeria

Dependent Variable (Annual rainfall totals)	**Explanatory Variable (Years)**	**Unstandardized Beta Coefficients (B) (Constant)**	**Correlation Values**
Ikeja	(1960-1987)	1923.4	-0.52*
	(1987-2009)	1556.7	-0.02
Ibadan	(1960-1983)	1368.5	-0.2
	(1983-2009)	1235.1	0.23
Ilorin	(1960-1987)	1314.7	-0.19
	(1987-2009)	1050.8	0.30*

* Correlation is significant at 0.05 confidence level (1-tailed).

The observed tendency towards wetter conditions in this study presents a significant hurdle to effective waste management in south-west Nigeria. Increasing trend of rainfall calls for concerns regarding waste runoff and concomitant polluting water, hence presenting hazards to the environment and public health (Hammed & Sridhar, 2019; Ogunbode & Ifabiyi, 2019; Ajaero et al., 2023). Moreover, massive rainfall events have the potential to accelerate landfill overflow, which might result in degradation of the environment (Echendu, 2020).

Policy and Management Implications

The results of this study call for a review of policy measures that support Sustainable Development Goal (SDG) 12, which emphasizes environmentally sound waste management coupled with responsible consumption and production. Important steps involve putting resource efficiency first, adopting the circular economy model, and including climate resilience into waste management plans (Jastrzębska, 2022; Reddy et al., 2023). Encouraging community participation in waste reduction efforts promotes responsibilities and ownership especially during high rainfall periods, which can effectively minimize the potential risk of pollution (Qureshi et al., 2023).

Keeping policy consistency across different sustainable development agenda is crucial to ensuring sustained positive outcomes and minimizing trade-offs (Amosun & Morakinyo, 2023). This study emphasizes how urgently waste management plans must incorporate proactive and flexible methods to successfully handle the increasing trend of rainfall occasioned by climate change in south-west Nigeria.

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ESTABLISHING A CIRCULAR ECONOMY HUB: A SUSTAINABLE SOLUTION FOR WASTE MANAGEMENT IN FEDERAL UNIVERSITY OF TECHNOLOGY, AKURE AND THE METROPOLIS

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ABSTRACT

Circular Economy is a system that must be employed in compliance with the United Nations Development Goals. This informed the basis for undertaken this study with a view to justify the establishment of a circular Economy Hub in FUTA as a proactive response to the challenges of waste management in the community and Akure Metropolis at large. Grounded in the principles of the circular economy and aligned with the UN Sustainable Development Goal this initiative seeks to address the prevalent issues of plastic, textile, paper and other waste materials within and outside the University campus. Through a combination of research practical demonstration, field survey and stakeholder engagement the circular economy hub aims to promote resource efficiency, reduce environmental degradation and foster sustainable economic development. This paper discusses the rationale behind the initiative its operational framework, challenges encountered and potential benefits. It explores the implications of the Circular Economy Hub for waste management practices, community engagement and the broader sustainability agenda. Outcome from this study will serve as blueprint and developmental roadmap for circular economy in Nigeria.

Key words: *circular economy, waste management, resource efficiency, stakeholder engagement, sustainable development goals.*

INTRODUCTION

The current liner economy system whereby raw materials are extracted, use in the production of items and later discarded after use as waste is having significant negative impacts on the natural resources use thereby contributing to biodiversity depletion, environmental pollution and climate change (UNDP, 2023). According to the report published by UNEP, 2024, only 7.2 % of used materials are currently being cycled back into the economies after use. It was reported that European Union generates more than 2.2 billion tonnes of waste annually (EU, 2023). This forms the basis for the development of Circular Economy model.

Circular Economy, 2018 observed linear economic models of take, make waste has failed both people and planet since this cannot solve the problems associated with the increasing population growth in GDP and real wages across the world. The World Economic Forum, 2022 reported that in a circular economic model, things are made and consumed in a way that minimizes the use of the world's resources; thereby cutting waste and reducing carbon emissions. Products are kept in use for as long as possible, through repairing, recycling and redesign – so they can be used again and again.

The idea of establishing Circular Economy Hub is conceived to accommodate the seven pillars of the Circular Economy within a particular frame and space (Balleto et al., 2022).

European Union, (2022) identified several factors that must be considered for a successful Circular Economy including a clearly defined mission hinged on the facilities/office and actions. It means impactful, practicable and tangible solutions that can demonstrate and pilot the transition. It is equally important that the vision of the hub is clear, with well-defined objectives, goals and milestones in the short, medium and long term. Through these concerted efforts, the Circular Economy Hub aspires to not only enhance resource efficiency but also mitigate environmental degradation while fostering sustainable economic development. Moreover, by aligning with the broader objectives of the UN SDGs, particularly Goal 12 (Responsible Consumption and Production), this initiative underscores its commitment to advancing the global sustainability agenda. Circular economy has been designed as a model to reduce materials use, redesigns materials and products in such a way that the resources are keep in circulation with minimal waste thereby making resources available for production (USEPA, 2023). Circularity has been embraced as a Sustainable Materials Management strategy to promote sustainable materials use, integrating actions targeted at reducing negative environmental impacts which invariably preserve natural resources used throughout the life cycle of materials (Khorasanizadeh et al., 2019)

METHOD

In commemorating the year 2023 World Environment Day with theme "BEAT PLASTIC POLLUTION", member of the Environment Conservation Club and Netlink Environmental Conservation Organization mobilized other relevant stakeholders to sensitize the community on the efficacy of the programme. Part of the activities line up to commemorate the event was the picking of plastic materials on the streets. At the end of sensitization awareness programme on the need to beat plastic in our environment and picking of plastic items, a total of 17.75kg of plastic materials including polythene bag chlorofolide, PVC, pet bottles were collected. A weighing machine obtained from the research laboratory in the Federal University of Technology, Akure was used to establish the weight of the materials. Two weeks after the sensitization, an awareness campaign and picking of plastic wastes, a capacity training workshop on up-cycling plastics was organized for unemployed youth and retiree in the society. A total of 25 participants were trained on the sowing of tote bags using fabric materials; use of plastic pet bottles for interior design and decoration. Others were trained on the use of disposable paper, textiles for production of other decorative items.

The plastic recycling chain conceptual frame work guided in the sorting of the plastic waste is presented below. The conceptual framework is design in such a way that each link in the chain has an impact on the others. The sorting method chosen, for example, was determined by the characteristics of the collected plastic trash (types, composition, and so on), and the final destination of the recovered product was determined by the quality of plastics collected.

Figure1: Plastic Recycling chain
Source: Researchers, 2024

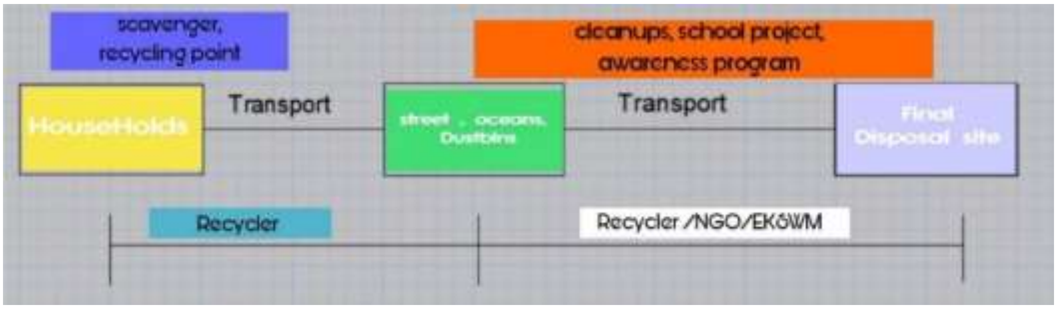

Figure 2: Collection model
Source: Researchers, 2024

RESULT AND DISCUSSION

Interactions with the trainees during the Circular Economy upcycling training revealed that the exercise has been impactful and meaningful. The skills and knowledge of the trainees were improved through production of tote bags, decorative and design materials that were displayed during the exercise. This findings were substantiated with information obtained through post assessment of the impact of the upcycling training exercise. It was further stressed that the skills and knowledge of the trainees were broadened on the production of tote bags, design and decoration. This support the findings of Bennet, 2023 that the benefits of upcycling is that it allows transformation of waste into valuable resources. Suhartini and Istighfari, 2020 opined that upcycling training is held to provide necessary skills and broaden the knowledge of the trainees on product development and community improvement.

The roles of Netlink Environmental Conservation Organisation , a Non-Governmental Organization in sustainable development, community improvement, environmental management and skill acquisition as demonstrated in this study cannot be over emphasized. ILO, 2018 observed that Local Government also play similar roles in skills integration and environmental management in countries such as China, France, the Republic of Korea, United Kingdom and United States (ILO, 2018b).

The mobilization of other environmental conservation organizations in Ondo State by the members of Netlink Environmental Conservation Organisation and Environmental Conservation Club, in awareness campaigns and beating plastic exercise during World Environmental Day, 2023 as reported in this study is a clear demonstration of the efforts to ensure a clean and hygienic environment in the community. The weight of plastic materials (17.75kg) collected within the space of three to four hours the picking and sensitization exercise were undertaken are clear indications that large amount of plastic waste is being used and disposed in the community. This shows that the social and economic lives of the people in the Akure community and the environs are directly linked to the use of plastic made materials. The social and economic impacts of plastic have been reported by Soumya et al., 2023. The authors observed that plastic contribute to change in the climate and induced environmental catastrophes. International Labour Organisation, 2018 that economic growth in many countries in Africa, Asia and the Pacific, and the Americas remains tied to GHG emissions, material extraction, water and land use.

The significant of the Circular economy in creating job for the unemployed has been observed in this study with over twenty trainees that participated in the organized Circular Economy upcycling capacity training within the period held in the Federal University of Technology, Akure. Circle Economy, 2017 opined that an estimated 8 per cent of the Dutch workforce is employed in circular economy jobs and the largest concentration of the jobs are in activities that promote reuse and recycling (Circle Economy, 2017). The World Circular Economy Forum(WCEF)- Sitra, (2016) the beneficiary of the Finnish Innovative Fund reported that circular economy supports competitiveness and a reduced dependence on imports.

CONCLUSION

In conclusion, the establishment of a Circular Economy Hub presents a sustainable solution to the pressing issue of waste management in Federal University of Technology, Akure, and the surrounding metropolis. By implementing circular economy principles, such as waste reduction, reuse, recycling, and resource recovery, the hub aims to transform waste into valuable resources while minimizing environmental impact. Through collaboration with stakeholders from academia, industry, government, and the local community, the Circular Economy Hub seeks to promote innovation, research, and education in waste management practices. By harnessing the collective expertise and resources of these stakeholders, the hub can develop and implement effective strategies for waste diversion, sustainable consumption, and green entrepreneurship.

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BLACK SOLDIER FLY, *Hermetia illucens*: A VALUABLE INSECT CONVERTING ORGANIC WASTE INTO BIODIESEL AND ANIMAL FEED

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ABSTRACT

Food crops produce for human consumption are wasted at different stages of processing; during transportation, in storage and after consumption. These leads to generate significant number of food waste on a daily basis. Solid waste management has been a global challenge for quite a long time, especially in developing countries. This waste management practice affects negatively human health and the environment. These challenges have inspired the search of alternate ways of disposing organic waste. A biochemical process to turn organic wastes by insect had been developed. One of the most widely used insect is *Hermetia illucens L.,* which is usually known as Black Soldier Fly (BSF). This insect is capable of utilizing food wastes to support its lifecycle, during which larvae digest and degrade food waste. BSF prepupae derived oil has a good fatty acids profile, which could potentially produce a high-quality biodiesel. Additionally, BSF prepupae, pressed cake, and meal has feed value comparable to commercial feed ingredients. Despite the benefits associated with BSF, there has been little information on the bioconversion of organic waste into biodiesel and animal feed via insects in Nigeria. Therefore, this paper aims at reviewing the findings of some previous works on the use of insect in turning organic wastes into biodiesel and animal feed.

***Key words**: Organic wastes, Black soldier fly, Biodiesel, Animal feed*

INTRODUCTION

Approximately 49% of the world population lived in cities and generated more than three million metric tons of waste (e.g., household items, food waste, packaging, ash) on a daily basis and by the year 2025, this number is expected to double (Cammack and Tomberlin 2017). A United Nations Development Program (UNDP) survey, conducted in 1997 in 151 cities revealed that, poor solid waste disposal is the second most serious problem after unemployment. This affects negatively human health, the environment and is a major set-back to economic growth (Manzano-Agugliaro *et al.*, 2012).

However, the current organic wastes management practices are not only costly but also have adverse impacts on environment such as ground and surface water contaminations and greenhouse gas (GHGs) emissions among others (Surendra *et al.,* 2016). These challenges have inspired the search of alternate ways of disposing organic waste. In recent years, the biochemical process to turn organic wastes by insect had been developed. One of the most widely used insect is *Hermetia illucens L.*, which is usually known as Black Soldier Fly (BSF). This insect is capable of utilizing food wastes to support its lifecycle, during which larvae digest and degrade food waste. They have been propagated not only as converters of organic waste but also a nutritious feed for chicken, pig breeding and aquaculture.

The immature stage is capable of converting the waste into a protein- and lipid-rich biomass suitable for various purposes such as animal feed, biodiesel and chitin (Wang *et al*., 2017).

This insect currently presents a worldwide distribution (Manzano-Agugliaro *et al.,* 2012). Though the problems associated with solid waste management is more challenging in the developing countries, little work has been done to explore the use of this technology in Africa. The present review provides a summary of the information available on the potentials BSF in converting organic waste into biodiesel and animal feeds.

Ecology and mechanism of BSF as raw materials for biodiesel production and animal feed

The black soldier fly (BSF) insect belonging to order Diptera and family Stratiomyidae, is a native to Americas and currently distributed throughout the tropical and subtropical regions around the world (Wang and Shelomi et al., 2017). The lifecycle consists of four stages, namely; egg, larvae, pupae, and adult. The larva is a voracious feeder of decomposing organic materials, such as manure, damaged feed, and kitchen scraps (Li et al., 2011).

The oil derived from BSF pupae contains a high percentage of medium chain saturated fatty acids (67% total fatty acids) and a low percentage of polyunsaturated fatty acids (13% total fatty acids), which shows that it could be a great substrate for the production of high-grade biodiesel (Surendra et al., 2016). However, important animal feed characteristics have been studied in the whole BSF larval and prepupae biomass which could be used as protein source for poultry, aquaculture, and livestock (Wang and Shelomi et al., 2017).

Their bioconversion rate, the ability to transform organic waste into valuable products, and final product optimization are key factors that enhance their potential as a nutrient-rich protein source, fertilizer, and biofuel (Siddiqui et al., 2023). Several variables can influence the bioconversion rate and the final product of BSF treatment (van Rozen et al., 2023). These variables include the type of organic waste used, the environmental temperature and humidity, and the density of the larvae (Cheng et al., 2017).

Process to convert organic wastes into biodiesel by BSF

The process to convert organic waste into biodiesel involved two main stages: first, BSF release strong digestive enzymes into the organic waste; second, these soluble organic molecules (such as sugar, amino acids, and fatty acids) transform the complex organic materials into grease, which was then extracted to produce biodiesel (Li et al., 2011).

A set of mechanical and chemical processes has been used to fractionate the BSF prepupae mixture into crude oil and cake/meal. Mechanical extraction is by using a lab-scale Taby Press Type 20, as described by Surendra *et al.,* (2016). The extracted crude oil is collected and centrifuged. The pressed cake following mechanical extraction is further chemically extracted using a Soxhlet apparatus and petroleum ether as a solvent. Afterwards; petroleum ether is removed using a rotary evaporator leaving crude grease. The crude grease from each sample is used for the further process.

Biodiesel production from BSF fat

Biodiesel production is carried out by two-step process as described by several Authors (Li *et al*., 2011; Zheng *et al*., 2012; Surendra *et al.*, 2006; Wang *et al.* 2017).

Step 1: Acid-catalyzed esterification

This is a pretreatment step which used to convert free fatty acids in the crude fat extracted into biodiesel, and to decrease the acidity of the crude fat. The upper layer (crude fat and biodiesel) is transferred to a reactor for alkaline-catalyzed transesterification.

Step 2: Alkaline-catalyzed transesterification.

In this step the upper layer (crude fat and biodiesel) obtained from the above step is mixed with methanol and the catalyst NaOH (0.8%, w/w). This mixture was then being placed in water bath for 30 min and stir with magnetic stirrer. After the reaction, the mixture is separated by gravity. The upper biodiesel layer is separated from the lower layer and purified by distillation to remove the residual methanol.

CONCLUSION

The present article reviews the literatures related to bioconversion of organic waste into biodiesel and animal feed via BSF. BSF is capable of utilizing food wastes to support its lifecycle. BSF immature stages derived oil has a good fatty acids profile, which could potentially produce a high quality biodiesel. Additionally, BSF prepupae, pressed cake, and meal has feed value comparable to commercial feed ingredients

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STEMMING THE TIDE OF MENACE OF ELECTRONIC WASTE: LAGOS EXTENDED PRODUCER'S RESPONSIBILITY PERSPECTIVE

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ABSTRACT

Electronics are such vital tools in our lives that they are used in nearly every human effort. However, the electronic wastes (E-wastes), which constitute out-of-date electronic devices that are no longer useful for the purpose for which they were designed, are a drawback. The paper aims to evaluate electronic waste management in Lagos by examining the level of adoption of Extended Producer Responsibility in driving E-waste management. The study adopted explorative review of relevant literature and analysis of interview with relevant authority to assess the level of adoption of EPR in handling E-waste in Lagos. This paper finds that relevant agencies have not done much in coming up with an actionable plan and policy guidelines that will cordinate, finance and mandate Ewaste actors into actualizing EPR with the state of E-waste management in the city dominated majorly by informal actors. The study therefore recommends institutionalization of EPR in Lagos to facilitate effective E-waste management system while synergizing with relevant authorities, investors and informal actors to ensure E-waste business opportunity inherent in E-waste becomes resource for other productive ventures.

Key words: *E-Waste, Extended Producer Responsibility, Informal Actors, Electronics, Out-of-date*

INTRODUCTION

It is established that most households have at least one electronic device, underscoring the fact that electronics are vital components of our daily life and their use in diverse sectors highlights their importance (Joseph, 2019). The products include refrigerators, washing machines, computers, tablets, cell phones among others (Kalantidou and Walsh, 2016) and are characterized by short life span. The shortened lifespan is an offshoot of the products' perpetual improvement for efficiency (Park, et al, 2017) and when the products attain end of their productive short life cycle they become electronic wastes (E-waste) (Adediran and Abdukarim, 2012). E-waste is the term used to describe the trash created by outdated electronic devices and is composed of dangerous materials like barium, mercury, lead and calcium which requires extra care in handling, as well as valuable resources that must be reclaimed (Akuru and Okoro, 2010).

While the global market for electrical and electronic equipment (EEE) has risen at an exponential rate over the last two decades, the products' characterized short lifespan portends great issues combating e-Waste on a global scale as the number of electrical gadgets continues to climb (Bhutta, Omar, and Yang, 2011). According to Akuru and Okoro (2014), around 4 million personal computers are purchased annually in Nigeria and the volume of e-gadget trade in Nigeria and Lagos in Particular is expected to rise further following rapid expansion in the adoption of information and communication technology (ICT).

Lagos, a major Nigerian commercial city with a population of over 15 million has the largest electronic users and possibly expected to generate the highest quantity of e-waste aside those inadvertently generated through imported used electronics (Alani et al, 2020). While state of the art E-waste processing facilities are not readily available in the country, imminent crude handling of electronic equipment in the city has raised questions on sound end-of-life handling (Manhart, 2011). With growing hazard of crude e-waste handling drawing the attention of stakeholders (Ideho, 2012), the need for policymakers and electronic manufacturers to come up with a viable solution for developing a long-term e-waste management system that incorporates consumers, informal sectors and manufacturers will guarantee the success of management system such as Extended Producers Responsibility(EPR) in Lagos. EPR measures are poised to create a workable collection system, management, recovery, and recycling of all electrical and electronic items (Gaidajis, Angelakoglou and Aktsoglou, 2010).

The program's widespread recognition as an effective waste management tool for expanding recycling and reducing product landfilling, has caused EU Member States to implement EPR schemes on the four waste streams (packaging, batteries, Vehicles and Waste Electrical and Electronic Equipment (WEEE) which EU Directives recommended. The initiative has led to producers of goods taking responsibility for managing the waste generated by their products (OECD, 2014). Acknowledging the importance of environmental sustainability, Swiss government initiated schemes that promote sound E-waste management through separation and other initiatives that make percapita collection of E-waste to be more than 15kg almost quadrupuling an EU target of 4kg percapita. The feat was achieved through engagement of four producer responsibility organizations (PROs)- SWICO, SENS, SLRS and INOBAT who are integral part of the collection system (Islam, Dias, and Huda, 2018). In the scadinavian, Norway and Denmark schematized collection of environmental fees from producers and importers to finance the collection and treatment of e-waste when selling EEE equipment. The processes operate through five approved Norwegian PROs for WEEE: Renas, ERP Norge, Norsirk, Recipio, and Serva while Elretur, ERP Danmark, LWF (light sources), Recipo, and Rene operate for the Danish (Andersen, Jæger, and Mishra, 2020)

The foregoing affirms EPR concept hovers around key system components of (a) gathering e-waste, recovering valuables like secondary raw materials, the separation of hazardous waste and its secure disposal (Widmer Schluep and Denzler, 2008). In the context of Africa and Nigeria in particular, Woggsborg and Schröder (2018) noted that most schemes have not included social elements and informal sector workers in e-waste management but financial and environmental bottom lines were given attention in the development of the Nigerian EPR programme.

With studies by Alani et al (2020); SPREP (2011) affirming I CT to be at the neucleus of most economies, mounting e-waste generation in the future is imminent. As posited by Manhart et al (2011), Nigeria domestic consumption of electrical and electronic devices is increasing rapidly thus snowballing into rapidly growing e-waste volumes. This reinforces EU (2010) assertion that fast-paced product development, replaceability, as well as product technology transition have been largely responsible for accelerated e-waste generation. While, e-waste is produced at a global rate of around 50 million tons per yea (United Nations University, 2019), only 20% of total e-waste are being technically recycled, leaving the remaining 80% unaccounted for (Dhillon and Sandu, 2020). The trend according to Popoola, Popoola, and Purchase (2019); Nnorom and Osibanjo (2008) and Azodo, Ogban, and Okpor, (2017) is described as uncontrolled and frightening especially when majority of the electrical appliances and electronic gadgets shipped from the developed countries into most developing nations have almost outlived their average life cycle before importation

In the maintime, concerns mount in the developing countries as they lack funds and resources to properly dispose of e-waste, even when many developed countries find it cheaper and more convenient to ship their e-waste to these developing countries (Park, et al, 2017). With sustainable E-waste management advocated, SPREP (2011) opines requirement of much coordinated, and environmentally sound approach such as E-waste prevention, reduction, collection, storage, and disposal. The aforementioned align with OECD (2014) EPR concept with inherent instrument mix in four categories that encourage or require manufacturers to bear the financial or organisational responsibility for their products throughout their lifecycle by:

a. Setting targets for the product or material's recycling and collection as well as providing incentives to customers to return undesired items to retail locations are two ways to meet the maker's or retailer's obligations to collect the product at expiration.
b. Market-based and economic strategies to achieve EPR aims, including measures that encourage producers to comply with EPR, such as deposit-refund programs, advanced disposal fees (ADF), material taxes, and upstream combination taxes/subsidies (UCTS) as in obtainable South Korea.
c. Setting standards on minimum amount of recycled material as required or imposed by industries themselves through voluntary programmes.
d. Supporting information educates the public and requires manufacturers to disclose information, such as through reporting requirements, product and

component labeling, consumer education regarding producer accountability and waste separation, and disclosure of product materials to recyclers.

In achieving the aforementioned, EU adopts Directive 2002/95/EC which restricts substances that can engender environmental problems while managing e-wastes. This is believed to increase the chances of financial gain from electrical and electronic equipment recycling (Gaidajis, et al, 2010).

In the same vein, Directive 2002/96/EC was developed to encourage more efficient resource use through recycling and re-use by reducing the quantity for landfills. In the context of the developed Nations, the environmental laws for recycling, recovering and disposal are extremely strict thus justifying high material recovery rate (Vats and Singh, 2014). Switzerland, for example, offers a blueprint for addressing the growing environmental problem arising from e-waste even when Switzerland is among the world's largest e-waste generators, creating 184 Kilotones of e-waste in 2016 (ITU News, 2019).

Developing countries on the other hand (including Nigeria) lack well-established infrastructure for managing e-waste, as well as appropriate enforcement and monitoring of hazardous e-waste (Omole, et al, 2015). According to Vats and Singh (2014) developing nations' cities such as Lagos, Nigeria face a possible e-waste phenomenon following a localized generation and a seeming unabated illicit imports. In the meantime, inclusiveness corresponding to attitudinal approach of waste separation from households must be encouraged so as not to jettison the idea entrenched in the buy-back scheme for high volume E-waste recovery (Omole, et al, 2015). The case of Lagos specifically requires a buy back system that can ameliorate the hazard of mounting E-waste in the city and with insufficient literature addressing E-waste from the perspective of EPR or take back scheme in Lagos, this paper seeks to reinforce the need for institutionalization of functional EPR as a tool for addressing E-waste issues in Lagos.

Extended Producer's Responsibilities Tools

EPR tools functions through material take back and economic instruments. The takebacks are segmented into; product takeback and recycling rate targets which mandate manufacturers/retailers to mop their products through PROs collective arrangement, voluntary Product takeback mandate and recycling rate target and mandatory takeback and targets with a tradable recycling scheme (Woggsborg and Schroder, 2018). Economic instruments are applied through Advance Recycling Fee, Deposit Refund Scheme and upstream taxes. Turaga and Bashker (2017) opined Pigouvian taxes address e-waste associated externalities thus applying corresponding marginal waste management cost tax charge to the consumer. Producers typically have the choice of creating privately owned e-waste management systems (collection and recycling systems) or coming together as part of a Producer Responsibility Organization (PRO), which is a centralized system. The essence of this is to actualize expections with respect to addressing e-waste collection, sorting, recycling and sound management that promote circular economy while minimizing carbon footprint(GACERE, 2023).

Understandably, the PRO is a separate company that establishes the infrastructure for managing e-waste and collects trash thereby taxing them upstream with a portion of the higher expense payment to PRO transferred to customers and reflected in product prices because the product is price-sensitive (Walls, 2011).

Materials and Methods

This article uses an exploratory analysis of EPR from established and emerging economies with and without an informal E-waste management system to determine what the most crucial feature of EPR is in tackling the expanding E-waste stream. The instances were compared in order to determine the stakeholders' roles in the upstream and downstream stages of the extended producer responsibility. This comparative analysis served as the foundation for identifying the key features and components of the extended producer responsibility in actual practice. The study further adopts qualitative approach through Content Analysis of IDI and Policy Documents to investigate the efforts of Lagos state government towards Electronics waste management.

E-Waste Scenario in Lagos

Currently, no official estimate of the volume of e-waste collected in Lagos exists. As a major market for various electronic devices, such as cellphones, the amount of e-waste generated in Lagos is expected to shoot up. With EPR and waste management policies still at infancy in Africa (OECD, 2014), Woggsborg and Schröder (2018) found that OECD guidelines published in 2001(with 2016 updated version) sparked a boom globally in EPR Policies adoption however sparingly in Africa with South Africa and Nigeria beginning in 2010 and 2016 respectively. interestingly, Nigeria faces similar EPR challenge with China as informal management system remains prominent thus jettisioning the drive to forestall unsafe practices that engender pollution.

In Lagos, Nigeria, evidence from a study revealed institutionalizing the required framework for E-Waste management remains challenging owing to the dominance of private sector and informal sector, that are yet to be integrated into e-waste management processes. As reliably gathered from the Lagos State Environmental Protection Agency (LASEPA), institutionalization, integration and registration of informal actors are major entry points in Lagos E-waste management scenario and efforts at getting the informal sector registered for collection exercises have not been successful as informal actors are declining registration and this in particular, constitutes a major setback to the process.

Given the aforementioned scenario, the dearth of adequate data on E-waste generation in the city remains a clog in the wheel of launching an action plan for processes that tend towards sustainability through the scheme. Therefore, a legal framework for ewaste funding will ensure tax assimilation and incentives into the product’s original price. As such an authority of the agency affirmed the state government effort in designing Deposit Return Scheme or takeback in order to secure funding from Global Environmental Fund.

CONCLUSION

The paper examined the state of E-waste handling with respect to institutionalizing frameworks for EPR in Lagos, Nigeria, Thus effectiveness of relevant regulatory agencies' response in addressing mounting E-waste in Lagos was assessed and the agencies have not done much in coming up with an actionable plan that will coordinate, finance and mandate Ewaste actors to actualize EPR. The state of E-waste management in the city indicates that it is majorly informally managed from collection to disposal, in a process that is characterized by poor and unsafe handling system. It thus finds the state to be currently working on getting policy guideline documents on E-waste management ready for implementation.

RECOMMENDATION

As reports have shown in some economies, EPR, with its tools have proved reliable in managing E-Waste. This same system could be institutionalized in Lagos to facilitate recycling and an effective E-waste management system to enhance business opportunities. Ewaste can be exploited and relevant authorities could synergize with investors to ensure E-waste becomes a resource for other productive purposes while supporting a zero waste economy initiative in the process. Thus importers, manufacturers of Electronics in Lagos are encouraged to collaborate with government to institutionalize a deposit return system for swift retrieval of EOL devices. This may take the form of involving relevant actors in charge of managing expired electronic gadgets by establishing a deposit return scheme with a significant value placed on the returned EOL electronic product. With the informal sector highly involved in waste recovery in Lagos, appropriate authorities are advised to identify and train informal actors on best handling practices to avoid associated hazards.

The informal actors can equally be educated on the need to get registered for inventory purpose as this will aid data and records pertaining EOLmaterials in circulation for onward decision on appropriate management.

Policy drafting is therefore needed so that formal and informal sectors can be captured for return schemes and for prompt evacuation of returned devices for management process while keeping abreast electronic material stock.

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ASSESSMENT OF LANDSCAPE CONNECTIVITY OF URBAN GREEN INFRASTRUCTURE FOR BIODIVERSITY MANAGEMENT IN IBADAN

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ABSTRACT

Urban Green Infrastructure (UGI) provides multiple benefits which are being greatly eroded by the forces of urbanization that are threatening the existence of biodiversity in various settlements of the city. The survival of human beings and other living organisms depend on biodiversity which is declining as a result of connectivity. The study therefore investigated the connectivity of green spaces in five local governments of Ibadan land using the combination of Geospatial Technology and Fragstats Metrics. Data were acquired through remote sensing technology. The Geographic Information System analysis was carried out to determine land use land cover analysis which were used for connectivity analysis with Fragstats Metrics for 2000, 2005, 2010, 2015, and 2020. The year 2025 was also modelled to establish probable occurrence of connectivity issues in the city. The analysis made use of seven indices such as Number of Patches (NPP), Large Patch Index (LPI), and Contiguity Index (CONTIG-MN) etc. using Fragstats Software. The study established inadequate connectivity of UGI in Ibadan with CONTIG-MN moving from 0.41 in 2000 to 0.13 in 2020 while Percentage of Landscape (PLAND) decreased from 10.62 in 2000 t0 4.04 in 2020 showing high degree of fragmentation of green spaces. This therefore recommends that the destruction of UGI in Ibadan needs to be halted to avoid further loss and decline of biodiversity in the city.

Key words: *Urban Green Infrastructure, Connectivity, Geospatial Technology, Fragstats Metrics, Fragmentation and Biodiversity*

INTRODUCTION

Urban Green infrastructure has been an important special component of human settlements because of wide range of services that render multiple benefits to human beings and other living organisms. Urban green infrastructure provides important connections between communities and nature (Silva *et al.,* 2018 and Pauleit *et al.,* 2019). These infrastructures are indispensable prerequisites for the good life in cities and it comprises near natural as well as culturally shaped open spaces that contribute to the safeguarding and protection of ecosystem services for human beings and enhancements of biodiversity (Federal Agency of Nature Conservation, 2017). They contribute immensely to urban environmental sustainability (Meijering *et al.,* 2018; Shackleton *et* *al.*, 2018; Gwedla *et al.*, 2019, Russo and Cirella, 2020; Cocks and Shackleton, 2020; Gelan and Girma, 2021; Puchol-Salort *et al.*, 2021; Stan, 2022 and Zhang *et al.,* 2022).

Cities depend on green infrastructure for the provision of biodiversity on which human survival depends (Zari, 2018). Biodiversity is a vital component that serves as an essential ecosystem services for liveable, healthy and well-functioning cities which are of immense benefits to the society and the economy (Fairbrass *et al.,* 2018). Urbanization that is occurring globally and threatens biodiversity (Kaczorowska and Pont, 2019; Mc Donald *et al.,* 2020; Nilon *et al,*, 2017; and Severijnen, 2018), is becoming major driver of fragmentation and the loss of biodiversity (Kaczorowska and Pont, 2019; La Pont et al, 2019; WBCSD, 2023; Garrah *et al.*, 2017; Severijnen, 2018; Kowarik *et al*,, 2020; Kirk *et al.,* 2021; Weisser *et al*., 2021). These modes of urban development is destroying vegetation and altering land use as people continue to migrate to the cities and transform the spaces. The increase in population which leads to habitat degradation is responsible for the loss of biodiversity that is proceeding at a rate that may face a mass extinction events of species (Barnosky *et al.*, 2011; Science for Environment Policy, 2015 and Milvwaukee Metropolitan Sewerage District, 2018, Weisser *et al*., 2022). With the trend that 60% of the world's ecosystem are degraded and used unsustainably (MEA, 2005; UNFAO, 2011; WBCSD, 2023), about 50% of the world population live in cities at the commencement of 21st century and 70% of human population expected to live in urban areas by 2050 (United Nations Human Settlement Program, 2012), the landscape connectivity of biodiversity components would be more threatened by anthropogenic developments.

Connectivity means the ease with which organisms move between landscape elements, the number of connections between patches, relative to the maximum number of potential connections (Lindenmayer *et al.*, 2005; Brierley *et al.*, 2006; Aune *et al.*, 2011 and CIEEM, 2018). This is to ensure biodiversity preservation for ecosystem function and integrity that are important to everybody (Graham and Witt, 2001; Bennett, 2004; Bennett and Mulongoy, 2006 and MEA, 2005). The landscapes are experiencing drastic change due to anthropogenic pressures, which include loss of habitats and fragmentation. Connectivity is measured in landscape connectivity which is a degree of spatial connectedness among landscape elements such as patches, corridors and matrix

Landscape connectivity is in many cases spatial-data-driven analysis. Landscape metric is measured using spatial matrix with FRAGSTATS software. Spatial metric is a quantitative index that describes structure and patterns of a landscape (Herold *et al.,* 2003). Landscape metrics integrated with GIS are useful tools for quantifying spatial land cover characteristics (Kong et al., 2012; Rafiee *et al.*, 2009), and widely used in studies on landscape variability over the years (Sun *et al.*, 2020; Liu *et al.*, 2021) both in terms of ecological and visual values (Sahraoui *et al.*, 2021). Fragstats is a model used to quantify the green space pattern by using landscape metrics in the local area (Kong and Nakagoshi, 2006 and Han *et al.,* 2002). It has also being used to analyze the distribution of green space in many studies, especially in studies regarding ecological networks that mainly consist of green spaces (Li *et al*., 2015; Kang *et al*., 2018 and Han *et al*., 2022). The study therefore sought the application of Fragstat software as a spatial metric to measure the connectivity of the green spaces of Ibadan urban area for effective management of biodiversity in the city.

Statement of the Problem

Urban green infrastructure is becoming grossly inadequate for the population of Ibadan city due to unguided growth and conversion of every available green space into physical structures of various dimensions. This is posing danger for the existence of biodiversity and also affecting the quality of life being experienced by humans and other habitats in various settings of the city. Majority of the green areas in the city are lost as a result of changes in land use land cover and are also affecting the quality of connectivity for effective performance of biodiversity functions. The extent of destruction of the green space needs to be ascertained for effective management of the biodiversity.

Methods

The city of Ibadan, located in the southwestern zone of Nigeria, the capital city of Oyo state and the third largest metropolitan area in Nigeria after Lagos and Kano (National Population Commission, 2007) is the study area of the research. Ibadan is directly connected to many towns in Nigeria by system of roads, railways and air routes. The whole Ibadan city consists of five local government areas- Ibadan north, Ibadan North West, Ibadan South West, Ibadan South East and Ibadan North East local governments. The population was about 2 million in 2006 and now estimated to be 3 million (UN, 2015).

Remotely sense data were obtained for 2000, 2005, 2010, 2015 and 2020 to produce the land use land cover of the city using geospatial analysis. Year 2025 was modelled to produce the land use land cover as well. The land use land cover analysis obtained from geographic information system analysis served as input into the FRAGSTATS software for the production of connectivity analysis. Seven different landscape metric, which represents structural features on the level of landscape and classes, was selected. The indices used are number of patches into (NP), mean patch area (AREA_MN), mean area perimeter ratio (PARA_MN), mean patch contiguity index (CONTIG_MN), largest patch index (LPI), percentage of landscape (PLAND) and area weighted mean patch area (AWMPFD).

RESULT AND DISCUSSION

Land cover maps at the class level were used to calculate landscape metrics in the FRAGSTATS software. Table 1 displays the results of landscape metrics over the past 20 years as well as a five-year forecast. In the built-up areas, the number of patches (NP) declined from 1143 in 2000 to 349 in 2020. The anticipated NP metrics in 2025 will be 177. The decrease in the number of built-up patches indicates that disjointed patches will progressively come together to create single patches. This is a reflection of the built-up land cover type's expansion and development in the research area. During the research period, NP in bare land decreased from 3097 in 2000 to 1284 in 2020. The loss of open space may result in changes in land use in the region. The replacement of these patches with greenspace or built-up land use is another factor that causes them to vanish. In the green area, the NP measure climbed from 1991 in 2000 to 2844 in 2020. The number of green areas would increase to 2912 by 2025. Disruptors may have separated the patches of green areas into smaller patches as a result of their effect. The development of residential spaces and the extension of the city, including green area and bare land, are indicated by the increase in the number of patches of green area and the reduction in built-up patches.

One of the indicators that showed the mean patch size was AREA-MN. The level of interspersion is indicated by the lowering of this metric. The built-up class has seen a rise in this statistic, whereas greenspace and bare land have seen a drop. As a result, the level of the metric for the built-up area in 2000 was 7.42, and it will be 12.90 in 2020. As a result, lowering this measure in the green and bare land areas indicates a drop in the mean of these patch types, indicating a drop in the level of interspersion classes. In the year 2000, the average patch size in the green area class was 14.73. In 2020, it was 6.17. The metric's level in the bare land class dropped from 4.23 to 4.22.

PARA-MN, which is the form of the patches, is expressed by the metric. It is a basic measure of the shape's complexity because it displays the circumference to area ratio. The closer the shape is to the rotating state, the smaller the ratio. As a result, based on the numbers of the metric in the classes, it was discovered that the green area and built-up classes decreased while bare land increased in each of the three classes.

The CONTIG-MN measure is one of the metrics for determining the degree of landscape patch integrity as well as the degree of landscape fragmentation. When the patches are entirely distributed and fragmented, the metric is 0. Contiguity is stated to be at its highest level when the landscape is formed by only one type of patch. Between 2000 and 2020, the built-up and bare land classes both increased. Green areas, on the other hand, decreased from 2000 (0.41) to 2020 (0.13), demonstrating increased contiguity and decreased interspersion in these classifications.

The LPI index shows which patch is the largest in total. According to this indicator, if the largest patch class shrinks, it could be a factor in land fragmentation. For example, in 2000, the green area class was 13.75, in 2005 it was 11.61, in 2010 it was 9.35, in 2015 it was 4.17, and in 2020 it was 2.14. The amount of the measure in the bare land class declined from 17.14 in 2000 to 2.14 in 2020. In the built-up class, this index increased from 59.06 in 2000 to 85.82 in 2020, indicating a relationship between the patches that created a larger patch.

The class percentage of the entire landscape is represented by the PLAND measure. The expansion of both land covers is shown by an increase in this metric in both the built-up and bare land classes. This statistic accounted for 62.36 percent of the built-up class in 2000. In 2020, it was 96.04. The reduction in class fragmentation and the establishment of new built-up regions are represented by the growth in the number and density of built-up patches. During the study period, the percentage of the landscape covered by the green area class declined due to the consumption of the green ecosystem by other land uses and land covers. 10.62, 9.62, 7.22, 6.27, and 4.04 were the scores, respectively. In 2000, 2005, 2010, 2015, and 2020, the outcomes of this metric on the bare land landscape were 27.02, 29.02, 36.23, 48.94, and 66.92, respectively.

The sum of all patches with 2 times the logarithm of patch perimeter (m) divided by the logarithm of patch area (m-2) multiplied by patch area (m-2) divided by total landscape area is calculated by AWMPFD. The raster formula is tweaked to compensate for the perimeter bias. In other words, the average patch fractal dimension (FRACT) of patches in the landscape, weighted by patch area, is equal to AWMPFD. AWMPFD results across the terrain did not change considerably during the study period.

Though, it is uncommon to have so many researchers examining the same landscape metrics in the same study area, it is important to note that some of the findings of this study are consistent with the findings of Saeedal and Aysan (2020). Adewale and Olayinka (2019) carried out a landscape metrics analysis of land use patterns and changes in suburban local government areas of Ibadan, Nigeria. Though their landscape metrics of interest were slightly different from the ones examined in this study, there were similarities in few common metrics. The study revealed that the NP in 2017 was 809 for the built-up areas, whereas in this study, the NP of built-up area in 2015, the closest study year to 2017, was 898 (Table 1). Furthermore, in their study, AWMPFD was 1.39 in 2017, while this study's results showed 1.33 in 2015 for built-up areas. Their results corroborate some of the results of this study. Another piece of research undertaken by Wang *et al.* (2014) corroborates these findings through the evaluation of landscape fragmentation which is the opposite of connectivity. Different indices were used, some of which were relevant to the findings in this study which showed that there are no perfect metrics for measuring habitat fragmentation (the opposite of connectivity). The findings of the research showed clearly that the options of the metric sets selected are sufficient for revealing the landscape characteristics.

Table 1: Land classes based on landscape metrics

Metrics	LULC	2000	2005	2010	2015	2020	2025
NP	Built-Up	1143	1043	902	898	349	177
	Bare land	3097	2975	2702	1793	1284	1007
	Green Area	1991	2312	2505	2692	2844	2912

AREA_MN	Built-Up	7.42	8.47	9.59	11.45	12.90	14.68
	Bare land	4.23	3.43	2.39	1.38	0.98	0.45
	Green Area	14.73	12.73	10.45	8.45	6.17	4.70
PARA-MN	Built-Up	1215.29	1015.23	1002.68	987.79	876.03	748.55
	Bare land	1195.68	1278.68	1320.21	1504.39	1799.49	1873.46
	Green Area	1242.11	1142.12	1053.55	1010.23	968.17	742.65
CONTIG-MN	Built-Up	0.12	0.34	0.65	0.76	0.79	0.85
	Bare land	0.14	0.17	0.19	0.20	0.24	0.25
	Green Area	0.41	0.24	0.19	0.15	0.13	0.11
LPI	Built-Up	59.06	68.05	78.00	82.03	85.82	91.64
	Bare land	17.14	13.51	8.06	3.08	2.14	1.54
	Green Area	13.75	11.61	9.35	4.17	2.14	1.17
PLAND	Built-Up	62.36	67.36	83.78	97.79	96.04	98.31
	Bare land	27.02	29.02	36.23	48.94	66.92	69.26
	Green Area	10.62	9.62	7.22	6.27	4.04	2.46
AWMPFD	Built-Up	1.42	1.33	1.33	1.33	1.29	1.23
	Bare land	1.32	1.31	1.13	1.12	1.28	1.17
	Green Area	1.24	1.12	1.31	1.31	1.15	1.21

CONCLUSION AND RECOMMENDATION

The connectivity of urban green spaces provides network for species landscape interaction. This provides linkages for habitats, species, communities and ecological processes at various scales. Seven indices of the spatial metrics were used in evaluating the connectivity of this green spaces. It was established that green areas continued to decrease in size from 2000 to 2020 thus leading to reduction in patch sizes and increase in fragmentation. This lower connectivity in Ibadan environment is an indication that biodiversity loss caused by anthropogenic activities is plaguing associated benefits of biodiversity in various settlements. This empirical evidence reviewed that existing green spaces in the city need to be effectively managed to halt further degradation of the biodiversity that provides ecosystem services on which human life and organisms well-being depend. Biodiversity which is appreciated and valued by Nigerians in different ways (National Biodiversity Report, 2015) and urbanization forces that are degrading the components at various scales need to be given much concern by the governments at all levels for its preservation.

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CLIMATE RESILIENCE: THE PRACTICE OF LOCALLY-LED ADAPTATION IN SUSTAINING AGRICULTURAL LIVELIHOODS

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ABSTRACT

Climate change is one of the most serious challenges to Africa's agricultural sector and food security due to its sensitivity and vulnerability to temperature and rainfall changes. Climate impacts on the local communities are high because they depend primarily on natural resources. Their dependence on agriculture, forestry, and fishing sectors makes them more vulnerable to climate-related impacts such as droughts, and floods, including shifting rainfall patterns, frequent weather extremes, herder-farmer conflict, loss of crop yield, and soil erosion, leading to uncertainty in crop and food production. These impacts can lead to significant economic losses, such as crop failure, livestock damage, and indeed food insecurity; threatening the agricultural and water ecosystems, with intensified competition for natural resources. With climate change and rising natural resource competition, providing food to a growing population has become increasingly challenging. The rural and local communities are highly vulnerable due to their heavy reliance on natural resources for livelihood and primary economic activities. Consequently, there is a need to make locally-led adjustments to the actual or expected climate and its effects to moderate harm or exploit beneficial opportunities. With the environment around us changing in unpredictable ways, people are reinventing their relationship with nature.

Thus, a need for the adoption of a locally adapted response that ensures climate resilience practices to ensure adjustments in ecological, social or economic systems in response to actual or expected climatic stimuli and their effects. To protect people, livelihoods, and ecosystems from climate change, adaptation is a crucial component. In other words, it means altering processes, practices, or structures to minimize potential damages or to take advantage of climate change opportunities. Local communities are developing indigenous adaptation solutions and implementing actions to respond to current and future climate change impacts.

This will require local research, led by local researchers, to inform law and policy developments that are evidence-based and reflect the lived experiences of affected communities as well as provide opportunities for collaboration and dialogue on climate resilience between researchers and policymakers. There is also the need to develop and implement relevant international and regional frameworks to ensure that all climate adaptation measures to address climate vulnerabilities take into account the specific needs of the locals: farmers, women, children, youth, persons with disabilities and other marginalized groups following relevant human rights and other instruments.

This study recommends coordinated practices and principles for climate resilience that integrates multiple locally-led adaptation response, including Indigenous solutions and local knowledge, to ensure climate-proofing and sustainability of agricultural ecosystems.

Key words: *Climate vulnerabilities. Locally-led Adaptation response. Climate Resilience. Indigenous Climate-smart Solutions. Sustainable future livelihoods. Rural and local communities.*

INTRODUCTION

About 3.3 to 3.6 billion people live in climate-vulnerable contexts, according to the IPCC report issued in 2022. The vulnerability of ecosystems and people to climate change differs substantially among and within regions, with the immense impact of climate change on rural communities.

Indigenous/local communities play a pivotal role in conserving and monitoring biodiversity, which is intertwined with their livelihoods and food security. When policies are designed with the local context in mind, they are more likely to be successfully implemented. This ensures that climate action is practical, achievable, and resonates with the local population. Involving local communities in the climate adaptation process fosters a sense of ownership and responsibility towards climate action. This increases the likelihood of successful policy implementation and sustainability of initiatives. This study aims to analyze the investments of local communities in climate resilience building and sustainable agricultural practices to build resilient societies and economies.

Abegunde, Victor O (2019) found that "Concepts such as Climate-Smart Agriculture (CSA) emerged to bring about an adjustment in agriculture to enhance food production while dealing with the changing climatic conditions and their increasing variability; as it enhances the resilience of agricultural systems by balancing the priorities between adaptation, mitigation, and food security" (p. 21).

Climate-smart agriculture includes locally-led adaptation practices that bring about a sustainable increase in productivity. Such practices prioritize the participation, knowledge and capabilities of local communities, as well as the development of synergies between different actors and stakeholders, to adapt to the challenges of a changing climate. These strategies are critical in building resilience to climate change impacts, particularly in vulnerable communities; and empower local communities to take action in addressing their unique adaptation needs, leading to more sustainable and effective adaptation plans. Ultimately, Climate-smart agriculture (CSA) has become popular as a practical solution for food insecurity in the face of climate change. The LLA approach positively contributes to strengthening the resilience of rural households against climate disturbances.

The results presented in this research provide impulses for local, regional, national and global policymakers and implementers on the inherent value and importance of climate-smart practices, and adopting climate resilience and locally-led adaptation approaches for broader climate action for the well-being and socioeconomic development of local communities. Interest in localizing climate-smart principles and practices is growing across the globe, with the focus on locally-led climate resilience response analyzing adaptation from the perspective of local communities and individuals in the lowest strata of decision-making possible. The research report is valuable because it provides valuable insights into the different adaptation strategies being employed at community levels to respond to the impacts of climate change which can inform policy decisions and future interventions.

METHODOLOGY

The approach and methodology involved a systematic desk study and literature review to collect and analyze relevant studies from academic journals, reports, and policy documents. The research strategy aimed to identify empirical studies that investigate the indigenous solutions and local knowledge of rural communities in both climate resilience building and sustainable agriculture practices; through a synthesis of a subset of literature relevant to the research keywords.

By synthesizing the findings of the identified studies, this research provides climate-smart practices and principles that help rural communities and local people adapt to climate vulnerabilities; through the adoption of a locally-led adaptation response. The research narrates the innovative and indigenous solutions communities are developing to adapt to changing environmental conditions. To ensure a sustainable future for rural communities and local livelihoods, this research takes a look at the harmonized practices and principles of climate resilience that integrates multiple locally-led adaptation response, including Indigenous solutions and local knowledge. The recommendation outcomes synthesized from climate-smart approaches and sustainable agricultural practices are provided to ensure climate-proofing and sustainability of agricultural ecosystems, including food availability, grown locally. However, the results presented in the research report are from a wide scope and can be generic, as there is no case study focused on specific communities. Nevertheless, the key messages suggested in this report can be applicable in many rural communities as indigenous solutions and local knowledge has some broader similar practices that apply from one catchment area to another.

RESULTS AND DISCUSSION

The climate resilience of the agroecosystems and socioeconomic livelihood is strengthened by community initiatives for collective action to improve the surrounding natural resources and ecosystems so that it advances the effectiveness of CSA practices and initiatives for a sustainable future. Local communities approach climate adaptation response in a way that uses several traditional knowledge and indigenous solutions. Their adaptation capabilities and resilience against climate change can be increased using methods specific to their environment. While national adaptation strategies feature a great deal of high-level planning and policy-making, adaptation at the local level is usually fast-paced and iterative. Adaptation practices and initiatives of these communities are primarily controlled by different agroecological zones, indigenous/traditional knowledge systems and cultural values. These adaptation practices have been underway for decades, albeit at a small scale.

Communities are using Indigenous solutions and local knowledge to inform decisions influencing the implementation of the adaptation responses; with evidence increasing of human responses to the impacts of climate change in Africa. However, understanding the effectiveness of these responses for adaptation to climate change across the diversity of African contexts is still limited. Despite the high reliance on climate-smart agriculture for climate adaptation by local/rural communities, the potential of indigenous solutions and local knowledge to contribute to adaptation through reducing climate risk or supporting transformative locally-led adaptation responses is yet to be established.

Local People in highly vulnerable areas are up to 15 times more likely to die in floods, droughts, and storms (compared to those in most resilient areas), thus, the need to scale up practices and infrastructure to enhance resilience, via mainstreaming effective and equitable climate action now will reduce losses and damages for nature and people. Community by community, the impact of climate change and the vulnerability of the locals differ, according to the different regions and environment/weather conditions. Contextually, they must develop relevant responses to climate risks, with solutions specific to cities and rural areas and the priorities of indigenous peoples. These solutions must be implemented with community priorities and governance at the forefront.

With the environment around us changing in unpredictable ways, people are reinventing their relationship with nature. This has come with immense creativity that can be tapped into climate-smart adaptation solutions, via learning from local and indigenous knowledge for climate adaptation response. Local and indigenous solutions add to our understanding of how to manage environmental change. Integrating and valuing the various indigenous knowledge and local solutions will not only enhance communities' ability to respond to climate challenges but will also promote a more equitable and effective adaptation and resilient response to climate challenges while ensuring the preservation of traditional practices and cultural heritage in the face of change.

Results obtained from the literature review and research studies show that local communities have much experience in integrating indigenous knowledge systems and practices as important adaptation strategies to combat land degradation and carry out natural resource conservation, biodiversity and forest restoration, renewable energy production, fisheries and aquaculture production, climate-smart agriculture and water resource management. Climate-resilient development within the agroecosystem by integrating measures to adapt to climate change will not only sustain growing food locally to fight hunger but also provide wider benefits, including improving people's health and livelihoods, with attendant emission and pollution reduction.

The initiatives and actions offer important entry points and opportunities for the government to build upon and scale up for broader climate adaptation actions. The government needs to take advantage of these opportunities to foster accountability and transparency by making sure that frontline communities are included in the decision-making process, with their needs forming an important part of the climate adaptation process.

According to Hideyuki Kubo (2023), “Taking collective action is particularly important for ensuring that natural resources and ecosystems are cared for, which in turn, strengthens the climate resilience of socio-ecological systems at the community level” (p. 2).

Climate-smart Principles

The Principles of Climate-smart practices are based on an integrated approach that can strengthen Climate Adaptation and Resilience. Locally-led Adaptation response and Climate Resilience of local communities are the two key approaches to ensure climate-smart practices; in addition to a country-driven, gender-responsive, participatory and fully transparent approach, considering vulnerable groups, communities and ecosystems. The principles that guarantee successful adaptation and resilience approaches include:

1. Enhanced ability of decision-makers to understand and plan for environmental change by putting people-centred and gender-sensitive analysis at the centre of climate adaptation. By integrating population data in climate adaptation planning, policymakers can provide a more comprehensive understanding of vulnerability and develop means for resilience.
2. Community resilience built through climate-smart investments that allow local farmers, women and young people to take a greater role in decision-making over their futures.
3. Elevation of creative, locally-led, and locally managed solutions to climate change, with strengthened accountability of decentralized government and nonstate actors to finance and deliver indigenous solutions.
4. Local solutions that promote equity and community engagement through inclusive decision-making to reflect communities’ diverse needs, concerns, and aspirations in the face of climate challenges.

5. Supporting local communities to identify priority needs and collaboratively plan for climate adaptation, with access to decentralized climate funding.
6. Establishing an Indigenous knowledge research hub and local advisory committee to guide on a system change to accommodate climate vulnerabilities and, in the process, thrive and recover from any eventuality.
7. Adaptation actions that are based on and guided by the best available science (funded research) and, as appropriate, traditional knowledge, knowledge of indigenous peoples and local knowledge systems, to integrate adaptation into socioeconomic and environmental policies and actions.
8. Extension services and Training vulnerable populations in sustainable agricultural practices, for improved crop production, while ensuring productivity and livelihoods can resist the stresses and shocks induced by climate change.

These are done with active and sustained engagement of stakeholders, including local communities, national, regional, multilateral and international organizations, public and private sectors, civil society and other relevant actors, as well as an effective management of local knowledge.

According to the Global Impact Investing Network (GIIN, 2023), **Outcomes of such an integrated climate-smart approach include:**

- Utilization of diversified cropping systems comprising polycultures, cover crops, and perennials, which fix nitrogen and other nutrients in the soil and do not require synthetic fertilizers;
- Resources are used more efficiently, with a decrease in water and energy inputs, waste, runoff, soil erosion, and carbon emissions from fossil fuels;
- Resilience to extreme weather events and decreased pest and disease pressures improved yield stability;
- Increase farm profitability and prepare for climate change-related events with a formalized risk assessment and management; community adaptation response which can range from building flood defences, setting up early warning systems for floods, and cyclones, switching to drought-resistant crops, advancing the development of new crop and livestock breeds that are weather- and disease-resistant to redesigning communication systems, and business operations;
- locally-led adaptation approach with the potential to improve and sustain livelihoods and health and to build resilient farming communities amidst changing rainfall patterns and extreme weather events; and
- purchasing or assisting in purchasing farmland or farming operations that use diversified cropping systems to conserve and enrich soils, have higher yield stability; and offer risk-management strategies to help farmers increase farm profitability by preparing for and adapting to climate change-related events.

These climate-smart principles and outcomes can and should be part of a longer-term response to ensure stability and resilience across societies, blunting the impact of current and potential future shocks.

Climate-smart Approach: Achieving Sustainable Climate Resilience through Integrating Indigenous Solution of Locally-led Adaptation Response into Community Climate Actions

According to the Global Center on Adaptation, locally led adaptation (LLA) unlocks, supports and leverages the high potential and innovative capabilities of communities to develop and implement solutions. LLA has been judged as an effective, equitable and transparent adaptation response to the burgeoning climate vulnerabilities affecting rural communities because it transfers authority to local stakeholders without expecting them to bear the burden of adaptation. This helps to build social resilience by helping communities prepare for and respond to climate-related impacts. LLA serves as an important source of innovation, showcasing approaches that can then be adopted by other communities and countries. By increasing the number and effectiveness of LLA efforts, national and global climate action can be better informed, more effective and more resilient. Thus, LLA is critical for effective national and global climate actions as it helps countries and the global community to ensure that adaptation efforts are tailored to the specific needs of local communities and that they are implemented in ways that are culturally, economically and politically appropriate.

One sure route to achieving the goals of Climate Action is through indigenous solutions and local knowledge which is enshrined in the integration and application of LLA as it allows local communities to define their path to adapting to climate change and create a plan that works best for them. This can be especially important in remote and rural areas, where local knowledge of the environment and climate patterns can be invaluable. Also, since local communities are often the first to feel the effects of climate change, LLA is therefore important to make them best equipped to identify potential problems, determine potential solutions and devise strategies to cope with these effects. Again, LLA can also play an important role in strengthening the resilience of communities by enabling them to plan, become more aware of the climate risks they face and develop strategies to reduce their vulnerability. This can help to ensure that communities are better prepared for the future impacts of climate change.

Integrating indigenous solutions of Locally-led Adaptation (LLA) response into a community climate action plan is a climate-smart approach that is crucial to achieving sustainable climate resilience. This is essential because it enables communities to develop their own locally appropriate mitigation and adaptation strategies based on an understanding of the local context. This is key for ensuring that solutions are tailored to the particular needs and climate challenges of each community. Additionally, LLA encourages local ownership and participation, which can help to ensure that solutions are implemented in a timely and effective manner. By taking the lead in the development of adaptation strategies, local communities can become more self-reliant, enhancing their capacity to manage and respond to the impacts of climate change.

The LLA approach integrates the knowledge, traditions, cultures and experiences of local communities, thereby shifting the existing condition from the current national adaptation top-down strategies to an effective framework that is more inclusive and sustainable. Overall, LLA is an important approach to addressing the impacts of climate change and can help to create more effective and equitable adaptation measures, as well as to build community resilience. However, effective and sustained use of LLA requires an understanding of the needs, priorities and contextual realities as well as the removal of barriers, constraints and challenges in terms of skills, funding and the leadership of local governments to effectively contribute to the implementation of climate action.

In LLA strategies, local stakeholders lead initiatives that are bottom-up and community-driven. These strategies are tailored to local needs, resources, and capacities. By utilizing this bottom-up approach, climate action could be unlocked even at the local level, where such actions are most urgently needed.

Climate-Smart Practices

According to Okeke, Chukwueloka et al. (2023), some combination of the knowledge, solutions and initiatives employed by the local farmers living in climate-resilient communities, in exhibiting climate-smart practices includes the following:

- use of all kinds of waste agricultural biomass and residues, such as sun-dried seed/nut shells, cassava peels, corn stover, leaves, roots, crop stalks, palm kernel shells, palm oil fibre, palm oil bunch and other waste generated during crop harvesting and processing, livestock and poultry waste and forest litter as substitutes for fuelwood to produce biogas for clean energy and reduce the cost of firewood used in processing the cassava into *garri*;
- use of agricultural waste to make charcoal briquettes, for biogas production, and as a green manure to replenish the soil nutrients and control soil/gully erosion;
- introduction of bitter leaf juice (*Vernonia amygdalina*) into the fishponds to reduce fish mortality because bitter leaf juice contains antioxidants that help in removing free radicals from the fishponds;
- cross-breeding fish farming to produce their hybrid which is very rugged and disease resistant; with a very low mortality rate, consumes less feed and can gain weight rapidly, thus ensuring return on investment;
- drilling deeper water boreholes for easy access to constant water availability; and installation of water treatment plants within the farm premises to treat the water and improve its pH before supplying it to the fishponds
- use of white and black plastic sheets to enclose the fish ponds containing the hatchlings and fingerlings, to control temperature, sunlight and any other external conditions;

- introduction of several types and mixtures of locally sourced feeds which are highly nutritious and oftentimes pelletised. The feeds are usually made up of crop grains (rice, millet, wheat, maize and guinea corn), fish-meal, certain vegetables and grasses and the innards of birds and animals.

Other locally-led adaptation response includes:

- Planting of erosion-resistant trees at soil/gully erosion sites to control soil erosion and prevent the evolution of rill erosion into deep gully systems by planting trees with deep root systems, such that the deep roots bind the soil, forming a soil-root matrix that is resistant to erosion. This method is a Nature-based Solution that is very cheap and effective and requires less labour, making it preferable for the women's groups in the community.
- Laying sandbags at active gully erosion hotspots is one of the simplest and cheapest ways of controlling gully erosion and shallow slope failures. The villagers lay sandbags at active erosion sites, mostly on farm roads, footpaths and other access roads frequently used for the transportation of agricultural produce to the markets or urban areas.
- The community members and the various women's groups make high ridges and mounds around vegetable beds and also utilise the raised-bed cultivation method to improve drainage, minimize waterlogging and soil erosion and control flood inundations during high-rainfall events. These practices are typically carried out by smallholder vegetable farmers in the community.
- The placing of logs in shallow ditches is one of the cheapest and most effective ways of controlling gully erosion in rural communities. The smallholder farmers place logs, such as the stems of palm and/or banana trees or plantains (*Musa sapientum* and *Musa paradisiaca*) and other woody biomass, in shallow ditches located along farm roads and footpaths to trap sediment and water.
- The community members practise contour ploughing and mixed cropping as two important strategies for soil and gully erosion control.

CONCLUSION

There is no doubt that small-scale agriculture is crucial to the provision of food and livelihoods in many African countries. The economy of several African countries is vulnerable to the effects of climate change due to the dependence of small farmers on rain-dependent farming. It is evident that climate change significantly affects the rainfed-dependent agricultural economy, leading to food insecurity. Climate change impacts, like shifting rainfall and temperature patterns, as well as droughts and floods, are primarily linked to the vulnerability of households. However, there has been a surge in the number and frequency of adaptation practices and initiatives in all of Nigeria's agroecological zones due to the increasing impacts of climate change.

According to Gemeda DO et al. (2023), vulnerability assessment is a prerequisite to designing climate change adaptation strategies. Assessing the vulnerability of local communities to climate-related hazards is a key aspect of climate change adaptation. Therefore, there is a need to develop and promote climate change vulnerability assessments and adaptation strategies for addressing climate change, especially as regards local to regional-scale vulnerability assessments and adaptation plans. This will precede allocating specific adaptation strategies and tactics to corresponding climate vulnerability. Such adaptation response entails integrating indigenous solutions of Locally-led Adaptation into an inclusive community climate action plan is a climate-smart approach that is crucial to achieving sustainable climate resilience.

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WASTE NOT, WANT NOT: A STUDY OF WORKER INSIGHTS INTO FOOD WASTE CAUSES AND PRACTICES AT FAST-FOOD OUTLETS IN IKORODU

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ABSTRACT

Food waste continues to be an unassuming yet significant contributor to landfill leachate pollution, greenhouse gas emissions and indirectly to increasing global hunger. Extant global studies have identified high population, culture, lifestyle and human behavior to be important factors driving food waste generation in the industrialized world. However, there are few comparative empirical food waste studies particularly in Nigeria that address waste drivers or food worker insights on food waste causes and practices in their outlets, nor its environmental implications.

The study quantitatively investigated food waste pattern across three selected fast-food outlets in Ikorodu, associated worker perceptions on waste causes and practices and the implications for environmental sustainability. Utilizing a cross sectional design, ten (10) staffers involved in the generation, segregation, and management of food waste were selected from three (3) fast-food outlets at Ayagburen, Sekumade and Ikorodu central and interviewed using a questionnaire. Data was analyzed using frequencies and percentages, Chi square and Anova analysis. End-of-day food waste weight was measured using a weight balance in kilograms (kg) on the two peak days of the week- Saturday and Sunday and was used in a food waste impact calculation. Results indicate more workers were female (66%), 90% were under 40 years, 60% had more than secondary school education. Main cause of waste was advance preparation of meals prior to demand (66.6%). 73% advocated burying waste but were unaware of safer methods. None practiced food recycling. Mean weekend food waste at the three locations ranged between 10.14kg and 15.67 kg, and there was no significant difference ($p<0.05$). The study highlights discrepancies in workers knowledge and practices that may compromise waste reduction efforts and can inform the development of targeted training programs and interventions.

***Key words**: Ikorodu, food waste, gas emissions, fast-food waste, food worker insights*

INTRODUCTION

Food insecurity has assumed a position of global economic and environmental importance given the current global statistics indicating the vulnerability of over 690 million people to hunger while more than 2 billion cannot afford to feed well (FAO 2020). Despite the prevailing knowledge that food supply must be increased to meet present and future demand, at least 33% of food produced globally is wasted (Food waste atlas 2018). Securing food supply by reducing waste within what is already produced is therefore significant enough to warrant its inclusion in the Sustainable Development Goals to mitigate the current and potential environmental, economic and social costs it portends for the society. The practical outworking of SDG 12 is to "ensure sustainable and responsible consumption and production patterns" by halving per capita global food waste at the retail and consumer levels before 2030 (UNEP 2021). Although, the Waste Resource and Action Programme (WRAP 2014) defines food waste as a combination of avoidable food waste, possibly avoidable food waste, and unavoidable food waste, food waste in this study was seen as food harvested for consumption that gets thrown away between the production and consumption stages of the chain (Amicarelli and Christian 2021; Chalak et al 2021). Costs are often seen in the economic terms of labor, resources, energy all wasted as food gets discarded. From the environmental perspective, 95% of discarded food often end up on landfills (Withanage et al 2020; Principato et al 2021), and subsequently cause leachate pollution asides generating greenhouse gases during decomposition (Mohammed 2019). Furthermore, sourcing landfill sites is challenging due to increasing urbanization and competing land-uses reducing available and acceptable sites. Although food waste generates strong negative undertones, benefits accruable from recovery efforts include composting and energy produced as biofuels using thermochemical or biochemical processes (Mohammed 2019).

Extant research on household food waste in the Global North indicate key waste drivers include food overproduction, safety and quality issues and even environmental change, while for a country as Nigeria food waste research is relatively recent. In the last two decades, Nigerian food waste has increased in complexity and volume significantly (Igberase and Okojie 2010), with an alarming global hunger index of 28.3, (Global Hunger index 2023), necessitating the need improve food usage by cutting down waste. This underscores the importance of understanding consumer behavior in attempts to minimize wastage resulting from either negligence or intentional decisions to throw food away. Adequately quantifying this is however challenging due to a paucity of comprehensive data (WEF, 2022). A few published works on local food waste have focused their attention on households detailing the link beween socio economic characteristics, income and food waste volume (Sunday et al., 2022, Akerele et al., 2017; Obianuju and Ikpeida 2021; Adetunji et al 2017; Olowa and Olowa 2017) but there is limited exploration of other categories such as the food service industry which is the least investigated (Stirnimann and Zizka, 2021) inspite of its role in generating 4-10% of purchased food for consumers outside their homes (Ratliff, 2023). Such explorations can contribute to the understanding of what drives food waste behavior while generating substantial positive impacts as freeing up such food, increasing profits for owners while reducing ecological footprint of producing more food.

A study on selected restaurants owners in a Northern Nigerian city indicated waste practices among a wide category of restaurant types but did not disaggregate the data given the large variation amidst such a population (Bello et al 2021) nor can such results be applied to other spatially varied locations like the south. Exploring this literature gap is crucial and this study therefore investigated human factors that contribute to food waste generation in 3 selected Ikorodu fast-food outlets alongside current food waste management attitudes, and an attempt to quantify the food waste generated by these establishments within a weekend using a food diary was made.

This study provides basic empirical data on food waste knowledge and management practices of restaurant workers which may help in identifying how new policy interventions may be more effective in curbing waste and strengthening food security. This contribution is imperative for establishing waste reduction initiatives in the country as it aids environmentally sound food waste practices.

METHODOLOGY

The study was conducted in Ikorodu, a Local Government Area (LGA) situated in Lagos State, Nigeria. Positioned to the North East of Lagos State and adjacent to Ogun State, Ikorodu is bordered by the Lagos Lagoon to the South. According to the 2006 Census, the enumerated population of Ikorodu was 535,619. Located approximately 36 km North of Lagos, the town's geographical location is characterized by its proximity to the Lagos Lagoon to the South, sharing a boundary with Ogun State to the North, and adjoining Agbowa-Ikosi, a town in Epe Division of Lagos State, to the East. The Ikorodu Division comprises significant towns such as Imota, Ijede, and Igbogbo, each with their own Local Council Development Area and traditional rulers (Obas). The predominant livelihoods of the Ikorodu populace include trading (commerce) and engagement in the farming industry.

The study was done with a cross sectional descriptive design using a proportionate convenience sampling technique to select a three (3) different restaurants in Ikorodu. These were designated Sample A, B and C for reasons of anonymity and to protect privacy. Ten (10) staffers from each of these study restaurants involved in the generation, segregation, and management of food waste, including managers (1), supervisors (2), cooks (4) and cleaners (3) were interviewed thirty (30) making the total number of respondents. Sample size was due to the actual limited number of staffs each restaurant normally employs.

Sample and Sampling Techniques

A combination of questionnaires, food waste diary and interviews were used to collect respondents' quantitative and/or qualitative data. The food waste diary used was especially unique involving one or more selected staff weighing the food waste and make notes on the quantity, type, and cause to allow information collection on quantities, sources, and reasons for disposal**.** The end-of-day food waste weight was measured using a weight balance in kilograms (kg) on the two peak days of the week- Saturday and Sunday. The food waste was collected in poly ethylene bags. Ethical permission was obtained from the managements of the three (3) different sampled food service managers, as well from the Department and taken to management authorities and their consent was gained. Informed consent was obtained from respondents and confidentiality ensured.

Method of Data Analysis

Data obtained was analyzed using the Statistical Package for Social Science (SPSS) software package. Frequency distributions and percentages were derived for variables and Chi square test was used to see if there were any changes in food waste management practices between the food service managers (e.g., knowledge, attitude, practice, and demographic background), with a statistical difference of 5%.

RESULTS AND DISCUSSION

Table 1: Socio-Demographic Factors of the Restaurants Workers

Variables	Frequency	Percentage (%)	Mean (X) X^2
Study Site			
Sample A	10	33.33	
Sample B	10	33.33	
Sample C	10	33.33	
Gender			
Male	10	33.33	
Female	20	66.67	
Age Group			
20 – 30	12	40.00	
31 – 40	15	50.00	
41 – 50	2	6.67	33.17
51 and above	1	3.33	
Educational Qualification			
No school at all	0	0.00	
Primary education	4	13.33	
Secondary education	6	20.00	6.10
Tertiary education	20	66.67	
Designation			
Manager	3	10.00	
Supervisor	5	16.67	
Cook	14	46.66	

Cleaner	8	26.67	
Monthly Income (Naira)			
< 10, 000	0	0.00	
10, 000 – 25,000	8	26.67	
26, 000 – 50, 000	2	6.66	44,100
Above 50, 0000	20	66.67	

Computed from field data, 2023.

1. Worker Demographics

The results shown in table 1 indicated that the average worker at fast foods restaurants in Ikorodu are female (66%) and more than 90% were below the age of 40. It was noteworthy that 86% of them had education up to and beyond the secondary/College level education.

Majority of these workers earned at least #44,000 monthly particularly managers, supervisors and some cooks. but there was no association between their income level and the knowledge level about waste reduction from the Chi square analysis $X_{cal} \leq X_{tab}$.

2. Restaurant Worker Food Waste Awareness About Causes and Solutions

Table 2 Attitude of Restaurant Workers towards Food Waste Management

Issues raised	Agree	Strongly Agree	Not Sure	Disagree	Strongly disagree
Food waste is a Threat to the Environment	14 (46.67)	13 (43.33)	0 (0.00)	2 (6.67)	1 (3.33)
Not Interested in Food waste issues	3 (10.00)	2 (6.67)	8 (26.67)	11 (36.66)	6 (20.00)
Proper Disposal is an Important management strategy	16 (53.33)	12 (40.00)	2 (6.67)	0 (0.00)	0 (0.00)
Improper food waste disposal brings about Public health problems	12 (40.00)	18 (60.00)	0 (0.00)	0 (0.00)	0 (0.00)
Advance food preparation contributes to food	16 (53.33)	4 (13.33)	8 (26.67)	2 (6.67)	0 (0.00)
Food waste should be buried instead of burning	16 (53.34)	6 (20.00)	6 (20.00)	1 (3.33)	1 (3.33)
I think food waste generation is high	13 (43.33)	8 (26.67)	5 (16.67)	4 (13.33)	0 (0.00)
Both the government and our organization an do better in managing food waste	17 (56.67)	9 (30.00)	3 (10.00)	1 (3.33)	1.(0.00)

From Table 2, at least 70% of these workers had a prevailing attitude that food waste generation was high within fast food restaurants in Ikorodu and it could be reduced. When asked about how they felt it could be reduced, most were not clear on how this could be achieved. They however identified the preparation of food in advance of meals being ordered to be the main cause of food waste (66.66%). More than 90% were not aware of or had ever participated in a food waste campaign before. At least half of the respondents (50%) were unsure of what organic waste collection was or if it had ever been practiced in their organization. Nonetheless, there was a clear consensus on the need to properly dispose of food waste, failure to do so held strong health implications for the public. It was interesting to note that almost all the respondents (86%) were open to receiving more information and trainings from government or private sector initiatives on improved methods for managing food waste.

3. Practice of Food Waste Management

A major finding was that food recycling (leftovers of unsold food being reused) was never done across the three restaurants. The main reasons adduced for this was the customers preferences for freshly prepared meals and this was strictly adhered to in a bid to protect brand identity and maintain profitability. Leftovers were usually trashed and evacuation of food waste was done daily by external contract waste disposal companies after the close of work each day. Prior to the waste being picked up, all the respondents indicated the practice of binning the waste before pick up and evacuation

Table 3. **Food waste audit over a single weekend of the Three (3) sampled restaurants**

Sample	**Sampling days**	**Food waste Mass (Kg)**	**Mean (X)** ±StD (kg)
A	Saturday	15.67	14.89±1.10
A	Sunday	14.12	
B	Saturday	10.98	12.05±1.51
B	Sunday	13.12	
C	Saturday	15.67	15.25±0.59
C	Sunday	14.83	

From table 3, the two (2) days food waste audit revealed the food waste ranged between 10.14 and 15.67 kg among the three (3) sampling points; A, B, C. Sample C had the highest mean food waste of 15.25 ±0.59 kg while Sample B had the least mean food waste of 12.05 ±1.51 kg and Sample A had a mean food waste value of 14.89 ±1.10 kg. From the Analysis of Variance (ANOVA) result there was no significant difference ($P<0.05$) volume weighed across the three restaurants.

The study reveals differences in the volume and practices of managing food waste between households and fast food outlets. More research into the place of food outside of the home is becoming more paramount as people get more mobile and journey to work trips more distant warranting the need for more street food and fast food patronage. These results indicate the pervasive limited knowledge on what food waste was, causes and ameliorative practices that could be adopted in spite of the reported high literacy levels among the workers. This points to a need for advocacy and enlightening campaigns that will start out with helping the general populace recognize food waste as a problem with implications for food security. In many developing countries especially Nigeria, food waste is commonly perceived as unwanted material with no intrinsic value. This view undoubtedly influences how food waste disposal is viewed, alongside the underlying notion of a Government saddled with solid waste management including food waste. Advocacy can bring more illumination on the collective and personal benefits proper food waste management will bring. The significance of the findings is instructive particularly for the government, food establishments, as well as researcher.

CONCLUSION

The study gives an insight into food waste issues in South-west Nigeria, the prevailing attitudes and beliefs that shape the behavior of restaurant workers towards food safety and the environment and provides a deeper comprehension of the human factors influencing such. This study contributes data that can help improve existing food safety protocols and behavior change interventions that ultimately affect public health particularly for fast-food consumers.

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EMERGENCE OF CLIMATE CHANGE; EN ROUTE TO BIODIVERSITY LOSS AND DESERTIFICATION IN NIGERIA

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ABSTRACT

In Africa, climate change has been widely reported to influence human environment and ecosystems. The study researched on the emergence of climate change; en route to biodiversity loss and desertification in Nigeria. A purposive sampling technique was employed in selecting 120 sample respondents who were interviewed using questionnaires. The respondents were picked from the six geopolitical zones covering Nigeria. Field data were analyzed using descriptive statistics, multiple regression and late model. Result shows that burning of fossils fuels (75.4%), deforestation (70.5%), gas-flaring (83.4%), farming practices (96.6%), overgrazing (87.2%) and urbanization (72.4%) were acceded as primary causes of climate change in Nigeria. Biodiversity is impacted through loss of local species ($P<0.01$), increased diseases infestation ($P<0.01$), mass mortality of plants and animals ($P<0.05$), spread of invasive species ($P<0.01$), and habitat fragmentation ($P<0.05$). Climate variables such as reduced rainfall ($P<0.01$), frequent drought ($P<0.01$), higher temperature ($P<0.05$), frequent floods ($P<0.05$), and wind erosion ($P<0.01$) were perceived causes of desertification in Nigeria. Controlled burning (88.4%), afforestation (69.1%), controlled gas flaring (71.4%), smart agricultural practices (77.5%), and controlled animal grazing (80.1%), were isolated as climate change mitigation measures in Nigeria. Late model result showed that climate change increased biodiversity loss and desertification in Nigeria by 78.7% and 82.8% implying that climate change has negative implication in Nigeria and its environments. The study recommends that policy framework in environmental development and conservation should be pursued in Nigeria to abate the negative impacts of climate change in Nigeria.

Key words: *Emergence of Climate Change, Biodiversity Loss, Desertification, Nigeria*

INTRODUCTION

Climate change is now a recognized phenomenon that harms ecosystems, biodiversity, the environment across world countries (Abbass et al., 2022). According to the Intergovernmental Panel on Climate Change, climate change is the variation in a particular region of the world between the usual climate circumstances (rainfall, temperature, wind, etc.) and a distinct but recurring set of climate variables (IPCC, 2023). Climate change results from the destabilization of the ozone layer caused by an increase in greenhouse gas (GHG) emissions into the atmosphere (IPCC, 2023). Again, it is caused by human-induced processes such the burning of fossil fuels, deforestation, and industrial processing. Other factors that contribute to the concentration of greenhouse gases include farming practices like overgrazing, continuous cropping, forest fires, and the use of organic fertilizers (Klingelhöfer et al., 2020). No doubt the environment and its suburbs are being affected by these practices leading to biodiversity loss and desertification. Furthermore, these practices intensifies the greenhouse effect and causes more global warming by adding massive amounts of greenhouse gases to those that already exist naturally in the atmosphere (Okon et al., 2021). The effects of climate change are also being felt in the form of rising ocean levels, melting glaciers, rising CO2 levels in the atmosphere, dwindling fauna and forests, and disruptions to aquatic life. However, climate change has negative implications for Nigeria environments (Ani et al., 2022); for instance, extreme weather events endanger both humans and the environment. Rainfall variations such as increased precipitation lead to an increase in land flooding which destroys our environment and ecosystems. Howbeit, delayed rainfall causes droughts and prolong-drought leads to biodiversity loss and environmental desertification (Olagunju et al., 2021). In addition, increase in the frequency and severity of temperature, frost, pressure, and heat waves causes' environmental degradation and denudation. Increased frequency of wildfires, increased wind and high relative humidity all have negative effects on the environment and ecosystems (Haider, 2019). Moreover, it is predicted that many plant and animal species will become extinct if this trend continues. There is a dearth in knowledge regarding the impacts of climate change on Nigeria environment, hence the motivation for the study.

MATERIALS AND METHODS

The study was carried out in Nigeria. Nigeria has an estimated population of about 229, 152, 217 million people. Nigeria forest vegetation includes the mangrove swamp, freshwater swamp, tropical rainforest and the savanna; guinea, derived, sudan, sahel savanna. Nigeria is characterized with three distinct climate zones; a tropical monsoon climate in the south, a tropical savanna climate for most of the central regions, and a Sahelian hot and semi-arid climate in the north of the country. Nigeria has two major coordinates 9.0820^{o} N and 8.6753^{o} E and has been bedeviled with climate change incidences leading to biodiversity loss and desertification problems. A purposive sampling technique was used in selecting 120 sample respondents who were interviewed using questionnaires. The respondents were picked from the six geopolitical zones covering Nigeria. Field data were analyzed using descriptive statistics, multiple regression and late model.

RESULTS AND DISCUSSION

Socio-economic characteristics of Respondents

The socioeconomic characteristics of respondents are shown in Table 1. The table shows that majority of the respondents 51.6% were between the age group of 41-50 years implying that they are old enough to experience climate change events. Majority 76.6% were males and females 23.4%. Majority, 75.8% were married and majority 32.5% attended tertiary education. Mean household size of the respondents were 6 persons per household. About 84.2% of the respondents have experienced climate change events as against 15.8%.

Table 1: Socio-economic characteristics of respondents

Variables	Percent age
Age	
20-30	7.5
31-40	18.3
41-50	45.8
51-60	28.3
Mean	
Sex	
Male	80.8
Female	19.2
Marital status	
Single	8.3
Married	48.3
Divorced	17.5
Widowed	25.8
Level of education	
Primary	15.0
Secondary	28.3
Tertiary	32.5
Non formal	18.3
Household size	
1-4	36.7
5-8	55.8
9-12	5.0
13-16	2.5
Mean	06
Experienced climate change events	
Yes	84.2
No	15.8

Primary Causes of Climate Change in Nigeria

The primary causes of climate change in Nigeria are shown in Table 2. About 75.4% of the respondents indicated burning of fossils fuels, 70.5% indicated deforestation, 83.4% opted for gas-flaring, 96.6% farming practices, 87.2% indicated overgrazing with 72.4%

opting for Urbanization. This generally implies that these practices are inimical to environmental development and management (Benson, 2020, and Dahiru et al., 2021).

Table 2: Primary causes of climate change in Nigeria

Primary Causes	Percentage
Burning of Fossils Fuels	75.4
Deforestation	70.5
Gas-Flaring	83.4
Farming Practices	96.6
Overgrazing	87.2
Urbanization	72.4

Perceived Causes of Biodiversity in Nigeria

The perceived causes of biodiversity in Nigeria are shown in Table 3. Loss of local species was significant at 1% implying that increase in disappearance of local species increases loss in biodiversity. Increased diseases infestation was positive and significant at 1% implying that as disease infestation rises, it leads to biodiversity loss. Mass mortality of plants and animals was positive and significant at 5% implying increase in death of plants and animals' cause loss in biodiversity. Again, spread of invasive species and habitat fragmentation were seen positive and significant at 1% and 5% respectively, this indicates that increase in invasive species and habitat disintegration cause loss in biodiversity (Ikehi et al., 2023 and Madaki et al., 2023).

Table 3: Perceived causes of biodiversity in Nigeria

Causes of Biodiversity	t-values
Loss of Local Species	4. 563
Increased Diseases Infestation	3.853
Mass Mortality of Plants and Animals	2.992
Spread of Invasive Species	4.022
Habitat Fragmentation	2.002

Perceived Causes of Desertification in Nigeria

The perceived causes of desertification in Nigeria are shown in Table 4. Reduced rainfall was positive and significant at 1% implying that decreased rainfall causes desertification. Frequent drought was seen positive and significant at 1% implying that regular drought seasons triggers desertification. Higher Temperature was positive and significant at 5% implying that rising temperatures initiates desertification. Frequent floods and wind erosion were positive and significant at 5% and 1% respectively. This indicates that as climate variables increases, desertification is imminent (IPCC, 2023).

Table 4: Perceived causes of desertification in Nigeria

Causes of Desertification	t-values
Reduced Rainfall	3. 324
Frequent Drought	4.542
Higher Temperature	2.331
Frequent Floods	2.891
Wind Erosion	4.900

Climate Change Mitigation Measures

The climate change mitigation measures are shown in Table 5. About 88.4% of the respondents indicated controlled burning as a mitigation strategy adopted in adapting to climate change. Afforestation was indicated by 69.1% of the respondents, 71.4% indicated controlled gas flaring, while 77.5% and 80.1% opted for smart agricultural practices and controlled animal grazing as climate change adaptation and mitigation techniques (Udeh and Ikpe, 2022).

Table 5: Climate change mitigation measures

Climate change mitigation measures	Percentage
Controlled burning	88.4
Afforestation	69.1
controlled gas flaring	71.4
smart agricultural practices	77.5
controlled animal grazing	80.1

Impact of Climate Change on Environment

The Impact of climate change on environment is shown in Table 6: From the result, all the parameter estimates appeared negative implying that incidence of climate change has negative implications on environment and biodiversity. Evident on the result are the LATE (WALD) and LATE (IV) which showed that climate change increased biodiversity loss and desertification in Nigeria by 78.7% and 82.8% implying that climate change has negative implication in Nigeria.

Table 6: Impact of climate change on environment

Parameter	z-values
ATE	-2.521
ATE 1	-1.663
ATE 0	-2.442
LATE (WALD)	-4.934 (0.787)
LATE (IV)	-4.231 (0.828)
ATE (IPSW)	-2.565
PSM	-0.6773

Significant at ***1%, **5% and *10%

CONCLUSION AND RECOMMENDATION

The study is of the opinion that climate change has caused devastating effects in the Nigeria environment. Findings reveal that burning of fossils fuels, deforestation, gas-flaring, farming practices, overgrazing, and urbanization were acceded as primary causes of climate change in Nigeria. Loss in biodiversity was observed through loss of local species, increased diseases infestation, mass mortality of plants and animals, spread of invasive species, and habitat fragmentation. Climate variables such as reduced rainfall, frequent drought, higher temperature, frequent floods, and wind erosion were perceived causes of desertification in Nigeria. Controlled burning, afforestation, controlled gas flaring, smart agricultural practices, and controlled animal grazing were isolated as climate change mitigation measures in Nigeria. Late model result showed that climate change increased biodiversity loss and desertification in Nigeria by 78.7% and 82.8% implying that climate change has negative implication in Nigeria and its environments. The study recommends that policy framework in environmental development and conservation should be pursued in Nigeria to abate the negative impacts of climate change in Nigeria.

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ENERGY TRANSITION AND ITS IMPLICATION FOR FOOD SECURITY IN RURAL BENIN: A REVIEW

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ABSTRACT

Energy insecurity is a pressing issue affecting rural communities in Benin, particularly in terms of access to clean energy for cooking and heating. This paper presents a comprehensive review of the existing literature on the interplay between energy security and food security in rural Benin. the findings highlight the direct impact of energy insecurity on food security of rural residents. Moreso, the degradation of natural resources particularly the natural forests exacerbate energy insecurity. The overuse and destruction of forest resources negatively affects the environment hampering rural development. Factors contributing to this degradation include demographic growth anthropogenic activities fires overgrazing agricultural expansion and erosion. These issues coupled with energy poverty leads to soil fertility issues, hindering agricultural productivity, trapping rural dwellers in a vicious cycle of poverty. Rural residents of Benin, primarily depend on biomass from forest for cooking and heating due to poverty and limited livelihood capital. However, this unsustainable use of natural resources damages the environment, leading to issues like erosion and low agricultural production. To diversify their livelihoods and improve energy security rural dwellers engage in various forest-based activities which can harm the environment. This paper discusses the need to address the damages caused by rural communities in pursuit of energy security and the transition to sustainable energy sources. This study ultimately contributes to understanding the complex relationship between environmental sustainability and food security in rural Benin. it emphasizes the importance of sustainable approaches to balance energy needs, agricultural productivity and environmental preservation in rural Benin.

Key words: *Environmental degradation, Energy Security, Food Security, Livelihoods.*

INTRODUCTION

Food security is defined by the World Food Summit as followed: “all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life.”. Such definition by the World Food Summit highlights a critical yet often understated factor: energy. Access to sufficient, safe, and nutritious food depends on energy particularly when cooking is involved. The nexus between energy and household food security is undeniable. Without energy access, food security remains elusive. While various energy projects have been implemented in rural areas by both the Government and other developmental partners, food insecurity continue to plague these regions. Sola et al (2016) points out that not all energy interventions prioritize food security, and the lack of substantial discourse within the energy sector regarding food security exacerbates the issue.

This literature gap underscores the need to comprehensively explore the interplay between energy security and food security especially in rural Benin. Kaya et al (2019) advocates for in-depth research into energy security to inform policies and actions by governments and stakeholders. Therefore, it is imperative to redirect research efforts towards unraveling the intricate relationship between energy and food security in rural Benin. Conducting a critical review of existing literature on energy security’s impact on food security in these regions is essential to bridge this knowledge gap and promote environmental sustainability while addressing food insecurity.

METHODOLOGY

This research is built on a literature review guided by a conceptual framework (Fig 1) on potential linkage between energy security and food security. This actually guided this literature review. This conceptual framework has essentially supported at classifying the work into some thematic areas. Five hypotheses were then formulated to show linkages between energy security and food security.

Hypothesis one: Energy poverty affects rural household resources in Benin
Hypothesis two: Energy access influence yield of rural household food.
Hypothesis three: In Benin, household rural diet choice and cooking practices largely depends on energy access.
Hypothesis four: Livelihood diversification, particularly the transition to cleaner and more sustainable energy sources can enhance food security in rural Benin
Hypothesis five: Awareness campaigns targeted at educating rural communities can play a vital role in bridging the gap between energy security and food security in rural Benin.

Literature search involved using Google Scholar and Manual search based on relevant terms. Key terms both in French and English were employed, resulting in 78 articles. After a rigorous three-stage screening process, fourteen articles aligning with the themes of energy and food security in rural Benin were identified for further examination and data extraction.

RESULT AND DISCUSSION

Hypothesis one:
Energy poverty significantly affects rural household in Benin. the scarcity of firewood, driven by urban expansion and deforestation forces women at traveling long distances for wood collection, straining both human and financial resources. As firewood becomes rare and more expensive, it burdens households' finances. Sustainable energy solutions are essential to alleviate these challenges and increasing income is associate with adoption of cleaner fuels.

Hypothesis two:
Energy poverty influences agricultural productivity in rural Benin. Household energy source choice is influenced by socioeconomic and demographic factors. When fuel is scarce, rural households' resorts to less preferred fuels like dung and agricultural residues negatively impacting soil fertility and agricultural yields which affect back food security.

Hypothesis three:
High electricity costs lead to alternative energy sources affecting the overall food consumption. Without electricity, improper cooking fuels result in unsafe food preservation practices affecting dietary choices and nutrition. Fuel scarcity forces reduces frequent meal and households rely on quickly cooked but less nutritious foods.

Hypothesis four:
Diversifying livelihoods and transitioning to cleaner energy sources can improve food security in rural Benin. Unsustainable agricultural practices driven by rising energy needs and environmental degradation make agriculture unsustainable. Off farm income positively impacts cleaner energy adoption and energy security.

Hypothesis five:
Forest resources degradation, primarily due to human activities stemming from poverty and population grown negatively affect the quantity of biomass its quality and thus impact energy and food security. Deforestation exacerbates energy poverty and reduces agricultural productivity and thus perpetuates the vicious cycle of poverty.

CONCLUSION

Overall, the lack of access to conventional energy sources such as electricity, in the country abed particularly rural areas, exacerbates the food security situation for rural dwellers, forcing them at employing unsafe methods for food production and preservation. Access to and availability of safe energy resources empower the rural dwellers, at becoming more effective and efficient in their productive activities, enabling them to utilize their time adequately for nutritious food production and income generation. Energy access, enhances rural household's autonomy and capacity at achieving food security as they gain education, through various communication channels. Therefore, sustainable energy solutions and income enhancement emerge as vital strategies to mitigate these challenges. Additionally, promoting livelihood diversification and cleaner energy adoption can bolster food security while preserving the environment. Furthermore, awareness campaigns are essential to address the root causes of energy poverty and deforestation, ultimately bridging the gap between energy and food security in rural areas. These findings underscore the urgency of holistic approaches to improve rural livelihoods in Benin.

EXTENSION WORKERS' KNOWLEDGE ON REGENERATIVE AGRICULTURAL PRACTICES IN KWARA STATE, NIGERIA

L. L. Adefalu, S. Ibrahim-Olesin, & O. A. Alabi

ABSTRACT

The study examined extension workers' knowledge on regenerative agricultural practices in Kwara state. A proportionate sampling of 80 per cent of the sample population was used to select 122 extension agents from each zone of the Kwara Agricultural Development Project, Agriculture and Rural Management Training Institute, and Nigerian Stored Product Research Institute. Interview schedules and well-structured questionnaires were used to elicit information from the respondents, while descriptive and inferential statistics were employed for analyzing the data. Findings of the study revealed that the mean age of the respondents was (42 years) and (95.8%) were married. Findings showed that the majority of the respondents are male (65.8%). The study also revealed the average years of respondents' working experience to be 11. The findings showed that most respondents (70.8%) had moderate knowledge on regenerative agricultural practices, with mean knowledge scores of 3.69 out of 5. While core practices like rotational grazing, no-till farming, and cover cropping were well understood, knowledge of silvopasture and agroforestry was limited. Regression analysis found years of experience as the sole significant predictor of knowledge levels ($p<0.05$). Increased training exhibited a positive correlation with higher knowledge ($p<0.05$). The study concluded that there was moderate knowledge on regenerative agricultural practices among respondents but they still have limited knowledge on some core practices. It is therefore recommended that Government should expand training programs on regenerative agriculture for extension workers and equip them with practical skills to improve their knowledge.

INTRODUCTION

Agriculture is undoubtedly considered a priority of countries' national security owing to its primary importance in the production of food necessary for existence (Beckman and Countryman 2021). The vitality of agriculture as an important component of lives of humans results from the importance of food being the oxygen of life (Hemathilake and Gunathilake 2022). More importance of food becomes manifest as the need to cater for the growing world population becomes pressing. This means, agricultural production is pivotal in tackling critical challenges of the world at the moment and in the future.

Sustainable agricultural development has been identified with the potency to obliterate nutritional inefficiency in Africa come 2050 with a minimal emission of greenhouse gases (Janssens et al. 2022). More understanding of sustainable agriculture incorporates nature-based agricultural management procedures that conserve agriculture and natural resources (Sustainable agriculture 2018), and cut excesses and wastes that negatively impact the environment (Abubakar et al. 2022). Conceived as a crucial component of sustainable agriculture as far back as in the 80s, regenerative agriculture has been identified with its ability in the enhancement and improvement of soil health and soil carbon (Giller et al. 2021). It incorporates the enhancement of soil biodiversity, improvement of the physical qualities of soil, and the reduction in the use of chemicals for soil nutrient improvement (Burgess et al. 2019).

There is however a dearth of information about the usage of regenerative agricultural practices by farmers in Kwara State, and Nigeria as a whole. Extension agents have been noted for their significance aiding both the adoption and utilization climate smart sustainable agricultural practices (Olorunfemi et al. 2020). Despite this, little is known about the knowledge of extension agents on regenerative agricultural practices in Kwara State, Nigeria. Against this background, this study seeks to determine the knowledge level of extension agents on regenerative agricultural practices.

METHODOLOGY

The study was carried out in Kwara state, Nigeria, and the extension agents considered for this study were selected from Agricultural and Rural Management Training Institute (ARMTI), Nigerian Stored Products Research Institute (NSPRI), Kwara State, and the Kwara Agricultural Development Project (Kwara ADP). The state consists of sixteen Local Government Areas under four ADP zones. A proportionate sampling method was employed in the selection of respondents for this study. The extension agents at ARMTI and NSPRI were less than the extension agents in any of the four zones of the ADP. In lieu of this, each zone of the ADP was considered as an entity. Thereafter, a proportionate sampling of 80% of the population in an entity was selected. Cutting across the six entities (four ADP zones, NSPRI, and ARMTI), 122 respondents were selected out of which 120 questionnaires were analyzable. Both descriptive and inferential statistics were used to analyze the collected data.

RESULTS AND DISCUSSION

Socio-economic characteristics of respondents

Table 1: Distribution of respondents by their socioeconomic characteristics (n =120)

Variable	Category	Frequency (f)	Percentage (%)	Explanation
Sex	Male	79	65.8	
	Female	41	34.2	
Age (Years)	≤30 years	2	4.2	Mean: 42 SD: 6.88
	31 – 40	37	30.8	

	41 – 50	66	55.0	
	≥50	12	10.0	
Marital status	Single	5	4.2	
	Married	115	95.8	
Educational status	ND	19	15.8	
	HND	25	20.8	
	BSc	64	53.3	
	MSc	11	9.2	
	PHD	1	0.8	
Religion	Islam	78	65.0	
	Christianity	42	35.0	
Annual income (₦)	≤500000	55	46.6	
	501,000 - 1000,000	52	43.3	Mean: 690100.00
	≥1,000,000	13	10.1	
Years of Experience	≤10	54	42.4	Mean: 11 SD: 5
	11-20	44	34.6	
	≥21	9	7.2	

Source: Field survey (2023), SD= Standard Deviation

Table 2 presents the socio-economic characteristics of the respondents. From the table, 65.8% were males, while 34.2% were females. This implies that extension workers in Kwara state are predominately male, and this agrees with the findings of Adesiji (2015) who reported a similar finding among extension agents in Kwara State. Majority of the respondents fell within the 41-50 age range (55.0%), followed by the 31-40 age range (30.8%). Only a small percentage of respondents were in the 20-30 age range (4.2%), with an average age of 42, this is in line with the findings of Olorunfemi *et al*. (2020) who also revealed the mean age of extension workers to be 40.2. The majority (95.8%) of the extension agents were married, while a small portion (4.2%) were identified as single. Since marriage comes with commitments, maturity and managerial experience (Kim et al. 2019), extension agents in the study area are expected to display more effectiveness in the services of extension delivery. Furthermore, the highest proportion (53.3%) of respondents held a Bachelor's degree (B.Sc), followed by Higher National Diploma (HND) (20.8%). Some respondents had obtained a National Diploma (ND) (15.8%), while a smaller percentage had pursued Master's degrees (M.Sc). This finding agrees with Olorunfemi *et al* (2018) that stated that most of the extension agents in Kwara state are educationally well trained. Professionally, the majority (42.4%) of the respondents had less than 10 years of experience. 34.6% had 11-20 years of experience, and a smaller percentage (7.2%) had 21 years of experience or more with an average of 11 years. This implies that respondents are quite experienced (Omotesho *et al* (2012). The annual income varied among the respondents, with 46.6% earning between 100,000 and 500,000 units, and a mean income within this range calculated at 690,100. Another significant proportion (43.3%) fell into the 501,000-1,000,000 range, while a smaller portion (10.1%) earned between 1,001,000 and 2,000,000.

Knowledge Level on Regenerative Agricultural Practices

Table 2: Respondents knowledge on regenerative agricultural practice

S/N	Regenerative agricultural practices	Perception Index
1	Rotational grazing	4.29
2	No till farming	4.13
3	Inoculation of soil	3.95
4.	Composting	3.93
5	Use of cover crops	3.88
6	Mulching	3.47
7	Use of organic fertilizers	3.43
8	Livestock integration	3.28
9	Organic cropping	3.26
10	Silvo-pasture	2.92
11	Agroforestry	2.86

From Table 3, Rotational grazing becomes expedient owing to the prolonged farmer-herders' conflict which was enhanced by traditional (open grazing) method of rearing cattle (Ibrahim-Olesin et al. 2021). No till has been identified with the ability of revolutionizing agriculture through the improvement of soil erosion, enhancement of water storage, improvement of soil quality, betterment of yield, and farm income. Inoculation of soil was also among the well-known regenerative agricultural practices by the extension workers. Inoculation of soil is one of the approaches of improving the behaviour of soil water based on ecosystem for the improvement of irrigation management of farms. Composting was another regenerative agricultural practice that the extension agents showed some knowledge about, maybe, due to its ease of preparation and effectiveness. Other well-known regenerative agricultural practice by the farmers was the use of cover crops (Oladimeji et al. 2020). Other less known regenerative agricultural practices by the extension agents were mulching (3.47), use of organic fertilizers (3.43), livestock integration (3.28), organic cropping (3.26), silvo-pasture (2.92), and the least known was agroforestry (2.86).

Table 3: Socio-economic characteristics of the respondents and their knowledge level on regenerative agricultural practices

Predictors	Coefficient Beta	Std Error	t-value	Sig.
(Constant)	5.6	8.082	0.000	
Sex	0.187	1.131	1.759	0.081
Age	-2.16	- 0.116	-1.378	0.171
Marital Status	0.000	2.584	-0.003	0.998
Educational level	-0.147	0.555	-1.493	0.138
Annual Income	-0.043	0.000	-0.444	0.658
Years of experience	0.320	0.151	2.199	0.030

Source: Field Survey (2023). $R^2 = 0.103$, Adjusted R= 0.047*P<0.05

Table 5 shows the socio-economic characteristics of respondents and their knowledge level on regenerative agricultural practices, the result shows that there is no relationship between the selected socio-economic characteristics of the respondents and their knowledge on regenerative agricultural practices. It also reveals that only years of experience as an extension agent had a statistically significant ($p < 0.05$) positive association with knowledge level of regenerative practices. The finding highlights the value of experiential learning and on-the-job knowledge accumulation. The result also indicates a positive correlation (R = 0.321) between the socio-economic characteristics of extension workers and their knowledge level on regenerative agricultural practices. However, the correlation is not very strong, as evidenced by the relatively low value of the coefficient of determination (R Square = 0.103) and the adjusted coefficient of determination (Adjusted R Square = 0.047) representing 4.7%. This suggests that other factors beyond the socio-economic characteristics might also influence extension workers' knowledge levels in regenerative agricultural practices.

CONCLUSION

The findings from this study suggest that extension workers in Kwara State, Nigeria have a moderate level of knowledge regarding core regenerative agriculture practices and their potential benefits. Respondents recognized the value of practices like no-till farming, cover cropping, and composting for improving soil health and mitigating climate change. Follow-up research should focus on quantifying regenerative agriculture's economic and environmental outcomes over conventional practices. A more concerted, demonstration-centered extension effort, along with policies that incentivize adoption, could help overcome barriers and encourage wider implementation of regenerative agricultural practices.

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EVALUATING THE IMPACT OF SERVICE LEARNING IN FOSTERING A CIRCULAR ECONOMY MINDSET

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ABSTRACT

This study investigates the impact of service learning on secondary school students' knowledge of the circular economy in Ibadan. The study used a mixed-methods approach, including pre- and post-intervention surveys, interviews, and qualitative analyses. The experimental groups were exposed to a service learning instructional strategy, while the control group was taught using a conventional strategy. The two groups were subjected to eight weeks of training. The collected data were analysed using descriptive and inferential statistics. The qualitative data were analysed thematically. Results showed that service learning significantly improved students' understanding of waste reduction, resource conservation, and its role in addressing environmental challenges. It also increased their willingness to adopt circular economy practices, leading to behaviours like composting, recycling, and waste reduction. The study recommends integrating service learning into education policies, prioritising teacher professional development, and revising the Economics Curriculum to promote interdisciplinary learning and address global sustainability issues.

Key words: *Environmental problems, Circular Economy knowledge, Sustainable practices*

INTRODUCTION

Nigeria, like many developing countries, faces numerous environmental challenges due to rapid urbanization, industrialization, population growth, and inadequate infrastructure. Key issues include air and water pollution, waste management, climate change, biodiversity loss, and inadequate sanitation. These issues lead to respiratory problems, environmental degradation, and health risks. Contaminated water sources affect aquatic ecosystems, fisheries, agriculture, and local communities' health (Olayinka, 2020; Gbadamosi, 2021). Several approaches have been taken to address them with minimal results, including policy reforms, community engagement, sustainable resource management, technological innovations, capacity-building initiatives, and collaboration among government, civil society, academia, and the private sector (Olayinka, 2020; Ellen MacArthur Foundation, 2021). Hence, school-based intervention is advocated for. A school-based circular economy programme is an educational initiative implemented within schools to promote sustainable practices, resource efficiency, waste reduction, and environmental stewardship (Ellen MacArthur Foundation, 2021). A school-based circular economy programme serves as a platform for fostering environmental literacy, empowering students as agents of change, and contributing to a more resilient, resource-efficient, and environmentally conscious school and society (Ellen MacArthur Foundation, 2021).

Studies reveal a significant knowledge gap among students regarding sustainable living, circular economy principles, and eco-friendly practices (Olayinka, 2020; Gbadamosi, 2021). Students lack awareness about waste management, energy conservation, and environmental stewardship, leading to poor practices like excessive single-use plastic use, inefficient energy consumption, and limited recycling efforts. This lack of a circular economy mindset, which prioritizes sustainability, resource efficiency, and waste reduction, highlights the need for educational interventions to address this gap and promote sustainable practices.

The challenge is unconnected to the use of conventional methods of teaching. The traditional method of teaching presents several challenges including passive learning, lack of relevance, limited interactivity, inadequacy of practical skills development, limited engagement with communities, and inadequate preparation for the future (Gbadamosi, 2021). These challenges highlight the need for a transition to more innovative and learner-centered approaches like service learning.

Service learning is an educational approach that integrates community service with academic instruction, allowing students to apply classroom learning to real-world situations while addressing community needs. By addressing the limitations of traditional teaching, service learning promotes critical thinking, reciprocal learning, where students not only contribute to community service but also reflect on their experiences, gain practical skills, and develop a deeper understanding of social issues and civic responsibility (Ho, Smith & Clark, 2024; Ajitoni & Gbadamosi, 2015).

It is noteworthy, that apart from teaching methods, there are some other factors that can influence students sustainable practices such as residence, school type. This study also look at influence of students residence on the students achievement. The study is is supported by Experiential Learning Theory (ELT), proposed by David Kolb, who suggests that hands-on experiences and active experimentation lead to more effective learning. Service learning aligns with ELT by providing students with real-world experiences and opportunities to apply theoretical knowledge.

Objectives of the study:

1. To examine the effectiveness of service learning initiatives in enhancing students' understanding of circular economy concepts such as adopting recycling practices, advocating for sustainable consumption, or engaging in circular business models.

2. To examine the effect of students residential type on their knowledge of circular economy

Statement of Problem:
The circular economy is a promising approach to address environmental challenges by promoting resource efficiency and waste reduction. However, there is a lack of understanding about how educational interventions, particularly service learning, can effectively cultivate a circular economy mindset among students. This study therefore, examined the impact of service learning on students' achievement of the circular economy and the effect of residence on students' achievement in circular economy.

Hypotheses
H_{01}: There is no significant main effect of treatment on students' circular economy knowledge
H_{02}: There is no significant main effect of residential area on students' circular economy knowledge
H_{03}: There is no significant two ways interaction effect of treatment and residential area on students' circular economy knowledge

Methods
The study adopted a mixed-method design (a pretest, posttest, and control group quasi experimental design and qualitative. It involved 52 (planned;38 unplanned 14) Senior Secondary students from two public and two private secondary schools in Ibadan. The study used a validated Circular Economy Knowledge Test (r= 0.85) to collect data, and teachers were trained for two weeks. The students were exposed to the treatment for eight weeks, followed by a posttest to determine the effect of the treatments. Data was analyzed using ANCOVA and Multiple Classification Analysis (MCA) to determine the performance of the various groups. All hypotheses were tested at a 0.05 level of significance.Qualitative data collected were analysed thematically to complement the quantitative data.

Results
$H_0$1: There is no significant main effect of treatment on students' Knowledge of circular economy.

Tests of Between-Subjects Effects

Dependent Variable: Post_Achievement

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	585.942[a]	4	146.485	14.483	.000	.552
Intercept	247.876	1	247.876	24.508	.000	.343
PreAchievement	3.399	1	3.399	.336	.565	.007

Treatment	540.434	1	540.434	53.433	.000	.532
RESIDENTIAL	.262	1	.262	.026	.873	.001
Treatment * RESIDENTIAL	7.801	1	7.801	.771	.384	.016
Error	475.366	47	10.114			
Total	5166.000	52				
Corrected Total	1061.308	51				

Table 1: Summary of ANCOVA of Students' Post- by Treatment and Residential Area

Table 1 shows that treatment had significant main effect on students' achievement in Circular Economy Concepts in economics ($F_{(1;\ 47)}$ =53.433; p<.05), hence the null hypothesis 1 is hereby rejected. The effect size is 53.2%. This implies that there is a significant difference in students' achievement in economics based on the treatment applied. Table 2 shows the magnitude of main effect across the treatment groups.

Table 2 : Estimated Marginal Means of Post-Achievement by Treatment

Estimates				
Dependent Variable: Post_Achievement				
			95% Confidence Interval	
Treatment	Mean	Std. Error	Lower Bound	Upper Bound
Experimental Group	11.638[a]	.576	10.479	12.796
Control Group	4.778[a]	.738	3.294	6.262

Table 2 shows that students taught using the Service-learning strategy had a higher post-achievement mean score (11.64) than their counterparts taught using the conventional strategy (mean=4.78) in economics.

Table 3: Bonferroni Post-Hoc Analysis of Post-Achievement in Circular Economy Concepts by Treatment

Pairwise Comparisons						
Dependent Variable: Post_Achievement						
					95% Confidence Interval for Difference[b]	
(I) Treatment	(J) Treatment	Mean Difference (I-J)	Std. Error	Sig.[b]	Lower Bound	Upper Bound

Experimental Group	Control Group	6.860*	.938	.000	4.972	8.747
Control Group	Experimental Group	-6.860*	.938	.000	-8.747	-4.972

Table 3 shows that there is a significant difference in the post-achievement mean score of students in the experimental and control groups (mean difference=6.86; $p<0.05$). This implies that the difference in the post-achievement mean score of students in the experimental and control groups is the source of the significant main effect of treatment.

$H_0$2: There is no significant main effect of residential area on students' achievement in circular economy.

The table 1 shows that the main effect of residential area on students' achievement in economics was not significant ($F_{(1;\ 47)}$ =.026; p>.05), hence the null hypothesis 2 is hereby not rejected. This implies that there is no significant difference in students' achievement in economics based on their residential area.

$H_0$3: There is no significant interaction effect of treatment and residential area on students' achievement in circular economy.

Table 1 shows that the interaction effect of treatment and residential area on students' achievement in economics was not significant ($F_{(1;\ 47)}$ =.771; p>.05), hence the null hypothesis 3 is hereby not rejected. This implies that there is no significant difference in students' achievement in economics based on the interaction of treatment and residential area.

Discussion of Results: Service learning significantly impacts students' achievement in Circular Economy Concepts, aligning with previous research on experiential learning and community engagement. This strategy promotes deeper learning outcomes and critical thinking skills by providing hands-on experiences. The impact of the treatment is demonstrated by some of the participants who reported that "*I no longer buy food in takeaway again, I now take my plate to food seller*". In another vein *"I keep my plastic bottles where those that use it to make liquid soap and zobo can find it rather than disposing it where it can cause pollution"*. The effect size of 53.2% indicates a substantial impact on students' understanding and performance, aligning with meta-analyses by Ho, Smith & Clark, 2024; Olagoke-Oladokun,, Mokhtar, Gbadamosi, & Dugguh, 2020). which reported medium to large effect sizes associated with service learning interventions in improving learning outcomes and student engagement.

The study found that students' achievement in circular economy economics was not significantly influenced by the type of residential area they resided in. This suggests that factors other than residential area type may have had a more substantial impact on students' understanding of circular economy concepts in economics. Environmental factors, such as access to resources and neighborhood characteristics, can influence educational outcomes, but their impact on academic achievement may vary based on various contextual factors and individual differences. It is crucial to consider the broader context of students' educational experiences, including teacher effectiveness, family support, and personal motivation, when interpreting the lack of a significant main effect of residential area type on academic achievement.This finding aligns with previous studies that found mixed or inconclusive effects of residential area type on academic achievement (Astbury, Walberg & Leibbrandt, 2020, Ajitoni & Gbadamosi, 2015).

The study found that the impact of service learning on students' achievement in the circular economy is not significantly influenced by their residential area, regardless of whether they live in urban, suburban, or rural areas. The findings suggest that the benefits of service learning are consistent across different residential areas, with factors such as student engagement, programme quality, and instructional strategies having a more substantial impact on academic outcomes than residential location. Therefore, the benefits of service learning in enhancing students' achievement in the circular economy remain consistent across different residential areas.

CONCLUSION

The study found that service learning is an effective educational approach for fostering students' circular economy mindset. It showed a significant improvement in students' achievement compared to traditional teaching methods, particularly in understanding and applying Circular Economy Concepts in economics. This suggests that active engagement, practical experiences, and community involvement contribute positively to learning outcomes and academic performance. However, the significance of students' achievement in Circular Economy Concepts was not uniform across all groups, suggesting potential factors beyond the teaching method influencing student performance.

Policy Implications of the findings

The study emphasizes the need for service learning to be integrated into education policies and prioritized by policymakers. It also suggests revising the Economics Curriculum to include service learning principles, promote interdisciplinary learning, and address global issues like sustainability. The findings also calls for a holistic approach considering social and individual factors to ensure fair and equitable educational opportunities for all students, regardless of their location.

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ASSESSING THE IMPACTS OF CLIMATE CHANGE ON DESERTIFICATION IN NIGER STATE, NIGERIA

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ABSTRACT

This study explores the impacts of climate change on desertification in Niger State, Nigeria. Desertification, exacerbated by climate change, poses significant challenges to ecosystems and communities in Niger State, Nigeria. This study examines the key drivers of desertification, its socio-economic impacts, and the effectiveness of adaptation and mitigation strategies. A survey was conducted among 120 respondents, revealing overgrazing and climate change-induced factors as the primary drivers of desertification, with deforestation, poor land management practices, and urbanization also playing significant roles. Respondents highlighted the complex interactions between climate change-induced factors, such as changes in rainfall patterns and increased temperatures, and their contribution to desertification processes. The socio-economic impacts of desertification were pronounced, including water scarcity, decreased agricultural productivity, increased poverty, and loss of biodiversity. While some adaptation and mitigation strategies are being implemented, there is a need for greater community involvement, policy support, and integrated approaches to enhance resilience and promote sustainable land management practices. These findings underscore the urgency of coordinated action to address desertification in Niger State, Nigeria, emphasizing the importance of holistic strategies that integrate climate change adaptation, sustainable development, and community empowerment.

Key words*: Desertification, Climate change, Drivers, Socio- economic impacts, Adaptation strategies.*

INTRODUCTION

Climate change are long-term shifts in temperature, precipitation patterns, and other atmospheric conditions on Earth, primarily driven by human activities such as burning fossil fuels, deforestation, and industrial processes. These activities release greenhouse gases (GHGs) such as carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O) into the atmosphere, leading to the enhanced greenhouse effect and subsequent warming of the planet (IPCC, 2021). While desertification is the process of land degradation in arid, semi-arid, and dry sub-humid regions, resulting from various factors such as climate variability, unsustainable land management practices, deforestation, overgrazing, and soil erosion. Desertification leads to the loss of vegetation cover, soil fertility, and biodiversity, transforming productive land into barren desert-like landscapes (Bai, *et al.,* 2018).

Desertification, driven primarily by climate change and exacerbated by human activities, poses a significant threat to ecosystems, livelihoods, and sustainable development in arid and semi-arid regions worldwide (United Nations Convention to Combat Desertification, 2019). Among these regions, Niger State in Nigeria stands particularly vulnerable to the impacts of desertification due to its geographic location and climatic conditions. Situated in the Sahel region, Niger State experiences recurring droughts, erratic rainfall patterns, and land degradation, making it highly susceptible to desertification processes (Boko, *et al.,* 2017).

The intertwining of climate change and desertification in Niger State presents a complex challenge that requires comprehensive understanding and effective intervention strategies (Ayoade, 2012). As temperatures rise and precipitation patterns become increasingly unpredictable due to climate change, the delicate balance of ecosystems in Niger State is disrupted, leading to soil degradation, loss of vegetation cover, and dwindling water resources (Oladipo, *et al.,* 2018). Consequently, these changes have profound implications for agricultural productivity, food security, biodiversity, and the socio-economic well-being of communities reliant on natural resources (Adebayo, *et al*, 2017). The study seeks to elucidate the complex interactions between climate change and desertification processes in the region.

Statement of the problem

Climate change can exacerbate desertification by altering precipitation patterns, increasing temperatures, and promoting extreme weather events such as droughts and heatwaves. These changes can lead to soil degradation, loss of vegetation cover, and desert encroachment, further exacerbating desertification processes (Safriel *et al.,* 2015). Desertification driven by climate change can result in the loss of biodiversity, as it disrupts ecosystems and reduces habitat suitability for various plant and animal species. This loss of biodiversity can have cascading effects on ecosystem functioning, ecosystem services, and the resilience of ecosystems to future environmental changes (FAO, 2020).

Furthermore, climate change-induced desertification can have significant socio-economic consequences, including reduced agricultural productivity, water scarcity, food insecurity, and increased poverty among affected communities. These impacts can exacerbate social inequalities, exacerbate conflicts over scarce resources, and undermine the livelihoods and well-being of vulnerable populations (IPCC, 2014). Also, desertification driven by climate change can trigger human migration and displacement as communities are forced to abandon degraded lands and seek alternative livelihoods elsewhere. This can lead to social tensions, conflicts, and challenges for host communities and receiving areas, particularly in regions with limited resources and infrastructure to support influxes of migrants (UNCCD, 2017).

Similarly, climate change-induced desertification poses challenges for sustainable development by undermining efforts to achieve environmental sustainability, poverty eradication, and food security goals. It can hinder progress towards the Sustainable Development Goals (SDGs) by exacerbating environmental degradation, social vulnerabilities, and economic inequalities (UNDESA, 2017). Overall, the impacts of climate change on desertification highlight the need for urgent action to mitigate climate change, enhance ecosystem resilience, and promote sustainable land management practices. Therefore, the study assesses the impacts of climate change on desertification in Niger State, Nigeria.

This research seeks to:

i. Identify the key drivers of desertification and climate change in Niger State.
ii. Explore the socio-economic impacts of desertification and climate change in Niger State.
iii. Assess the current adaptation and mitigation strategies employed by stakeholders in Niger State

Significance of the Study

Ultimately, the findings of this research are expected to contribute to the scientific understanding of desertification-climate change dynamics in Niger State and inform evidence-based policy interventions aimed at promoting sustainable land management practices, enhancing resilience, and fostering inclusive development in the region. By addressing the pressing issue of desertification in Niger State, this project endeavors to contribute to the broader global efforts towards achieving the United Nations Sustainable Development Goals and building a more resilient and sustainable future for all.

LITERATURE REVIEW

Theoretical Review

This work discussed the Vulnerability, Resilience, and Adaptation (VRA) Framework.

Vulnerability, Resilience, and Adaptation (VRA) Framework (Adger, 2006)

The Vulnerability, Resilience, and Adaptation (VRA) framework provides a theoretical lens for understanding how socio-ecological systems respond to environmental stressors, such as climate change-induced desertification. This framework is grounded in the idea that vulnerability, resilience, and adaptation are interconnected dimensions that shape the capacity of individuals, communities, and ecosystems to cope with and adapt to environmental changes. The theory assumes that vulnerability and resilience is influenced by factors such as exposure, sensitivity, adaptive capacity, diversity, connectivity, and feedback mechanisms. While, adaptation involves adjustments in behavior, policies, and practices to manage risks and exploit opportunities (Adger, 2006).

The VRA framework provides a comprehensive approach to analyzing climate change impacts on desertification by considering multiple dimensions of vulnerability, resilience, and adaptation. The VRA framework can also be complex and challenging to operationalize, requiring interdisciplinary collaboration, data integration, and participatory approaches to effectively capture the dynamics of vulnerability, resilience, and adaptation. However, the VRA framework is highly relevant to assessing the impacts of climate change on desertification in Niger State, Nigeria, as it offers a systematic approach to understanding the complex interactions between socio-ecological systems and environmental stressors. Some critics argue that the VRA framework oversimplifies the complexities of socio-ecological systems and may overlook important contextual factors, such as historical legacies, power dynamics, and cultural dimensions, which shape vulnerability and adaptation (Alhassan, 2021).

Empirical Review

A study carried out by Alhassan (2021) on the Implications of Climate Change on Agriculture in Nigeria. The author conducted a literature review to gather information on climate change impacts on agriculture in Nigeria. Additionally, statistical analyses were employed to analyze trends in crop yields, temperature, and precipitation data. The study likely found that climate change has negative implications for agriculture in Nigeria, including reduced crop yields, water scarcity, and decreased food security. They recommend that implementing adaptation strategies such as drought-resistant crop varieties, improved irrigation techniques, and sustainable land management practices to mitigate the impacts of climate change on agriculture. The study concludes that climate change poses significant challenges to agricultural sustainability in Nigeria and emphasizes the importance of proactive measures to enhance resilience and food security.

Oladipo & Akinnubi (2020) conducted a study on monitoring and Assessment of Desertification in Nigeria: A Remote Sensing Approach. The research focuses on monitoring and assessing desertification trends in Nigeria using remote sensing techniques. The authors utilized remote sensing data and GIS technology to analyze changes in land cover, vegetation density, and soil characteristics associated with desertification. The study involved image processing, classification algorithms, and spatial analysis techniques. Findings of the study likely identified areas experiencing desertification and quantified the extent and severity of land degradation in Nigeria. It also detected trends in desertification over time. They recommend that targeted interventions such as reforestation, soil conservation, and sustainable land management practices to combat desertification in the identified hotspot areas. Potential criticisms could include uncertainties associated with remote sensing data accuracy and limitations in ground-truth validation.

Another study was carried out by Chukwuma & Odeyemi (2021) on climate Change Impacts and Adaptation Strategies in the Northern Region of Nigeria. A literature review to synthesize existing knowledge on climate change impacts and adaptation strategies in northern Nigeria was used. The result of the study highlights the vulnerability of the northern region of Nigeria to climate change impacts such as increased temperatures, decreased rainfall, and heightened risk of droughts and floods. It also identifies adaptation measures being implemented or proposed in the region. They recommend scaling up adaptation efforts, strengthening local resilience, and integrating climate change considerations into development planning and policy frameworks in northern Nigeria.

Ogunsanwo *et al.,* (2021) conducted a study on the assessment of Desertification in Nigeria Using GIS and Remote Sensing Techniques: A Case Study of Katsina State. The authors employed GIS and remote sensing technology to analyze changes in land cover, vegetation density, and soil characteristics indicative of desertification. The research findings identified areas of Katsina State experiencing desertification and quantified the extent and severity of land degradation. It may have also assessed the drivers and impacts of desertification in the region. The authors may recommend implementing targeted interventions such as afforestation, soil conservation, and water management strategies to mitigate desertification in Katsina State.

Further research by Oludare & Alamu (2021) conducted a study on the impact of Desertification on Livelihood Sustainability in Borno State, Nigeria. The authors employed a mixed-methods approach, combining quantitative surveys and qualitative interviews to assess the socio-economic impacts of desertification on local communities in Borno State. findings show that desertification has negative implications for livelihood sustainability in Borno State, including reduced agricultural productivity, loss of grazing lands, and increased vulnerability to food insecurity and poverty. The authors recommend implementing livelihood diversification strategies, promoting sustainable land management practices, and enhancing community resilience to mitigate the impacts of desertification on livelihoods in Borno State.

METHODOLOGY

The study used a cross-sectional research design. A stratified random sampling technique was employed to select 120 respondents for the study. Descriptive statistics and multiple regression analysis were used to analyze the data in order to determine the objectives.

RESULTS AND DISCUSSION

These sections provide the result of finding from 120 respondents used.

Table 1: Perceived Main Drivers of Desertification in Niger State

Main Drivers	**Frequency ***	**Percentages**
Deforestation	75	16.85%
Overgrazing	85	19.10%
Poor land management practices	60	13.48%
Climate change-induced factors	95	21.35%

Urbanization	40	8.99%
Agricultural expansion	65	14.61%
Mining activities	25	5.62%

Source: Field survey, 2024. ***** Multiple responses

From Table 1, it can be observed that the majority of respondents identified overgrazing (19.10%) and climate change-induced factors (21.35%) as the main drivers of desertification in Niger State. Deforestation (16.85%), Agricultural expansion (14.61%) and poor land management practices (13.48%) were also commonly cited factors contributing to desertification. Regarding other factors specified by respondents, they included soil erosion, population growth, and industrial activities. These results indicate a widespread recognition of multiple drivers contributing to desertification in Niger State, with climate change being a significant concern.

Table 2: Socio-Economic Impacts of Desertification on Local Communities in Niger State

Variables	**Coefficients**	**Std. Error**	**t-ratio**	**p>/t/**
Constant	-. 0154852	. 1282692	-0.12	0.905
Decreased agricultural productivity	.2658902	.0504679	5.27	0.000
Water scarcity	.3147452	.0638522	4.93	0.000
Loss of biodiversity	.2026354	.0675128	3.00	0.003
Displacement of communities	.1568927	.0617136	2.54	0.012
Increased poverty	. 1027249	. 0553847	1.85	0.067
Conflict over natural resources	. 0847515	.057355	1.48	0.141
R-Square	0.6943			
Adjusted R-Square	0.6763			
F-value	42.86			

Source: Field survey, 2024.

The multiple regression analysis results indicate a statistically significant relationship between desertification (dependent variable) and the independent variables. Findings shows that decreased agricultural productivity (coef. = 0.266, $p < 0.001$), water scarcity (coef. = 0.315, $p < 0.001$), loss of biodiversity (coef. = 0.203, p = 0.003), displacement of communities (coef. = 0.157, p = 0.012) and increased poverty (coef. = 0.103, p = 0.067) were positive and have a statistically significant impact on desertification and climate change. While conflict over natural resources does not show a statistically significant relationship with desertification and climate change (coef. = 0.085, p = 0.141), suggesting that conflict over resources may not be a major driver of desertification on climate change in Niger State. Efforts to combat desertification should consider these key factors and implement targeted interventions to enhance resilience and sustainable land management practices.

Table 4: Effectiveness of Adaptation and Mitigation Strategies

Observations	**Frequency ***	**Percentages**
Insufficient implementation and enforcement of existing policies and regulations	80	27.12%
Lack of community involvement and awareness-raising initiatives	70	23.73%
Need for integrated approaches that combine traditional knowledge with modern technologies	65	22.03%
Importance of sustainable land management practices and reforestation efforts	80	27.12%

Source: Field survey, 2024. ***** Multiple responses

Findings of the study show that diverse opinions were expressed regarding the effectiveness of adaptation and mitigation strategies implemented to address desertification in Niger State. Common themes included insufficient implementation and enforcement of existing policies and regulations (27.12%), lack of community involvement and awareness-raising initiatives (23.73%), need for integrated approaches that combine traditional knowledge with modern technologies (22.03%) and importance of sustainable land management practices and reforestation efforts (22.03%). These results suggest that while some adaptation and mitigation strategies are being implemented, there is room for improvement in terms of their effectiveness and inclusivity. Overall, the findings from this study highlight the urgent need for coordinated action to address the key drivers of desertification, mitigate its socio-economic impacts, and enhance resilience among local communities in Niger State, Nigeria.

CONCLUSION AND RECOMMENDATION

In conclusion, the findings from this comprehensive analysis provide valuable insights into the impacts of climate change on desertification in Niger State, Nigeria. The survey results indicate that deforestation, poor land management practices, overgrazing, and climate change-induced factors are identified as the primary drivers of desertification in the region. Moreover, respondents highlighted the intricate relationships between climate change-induced factors, such as alterations in rainfall patterns and rising temperatures, and their contributions to desertification processes. These findings underscore the multifaceted nature of desertification and emphasize the necessity for comprehensive strategies to address its underlying drivers effectively. Furthermore, the survey findings underscore the significant socio-economic impacts of desertification on local communities in Niger State, including water scarcity, decreased agricultural productivity, increased poverty, and loss of biodiversity. These impacts highlight the vulnerability of communities to environmental degradation and underscore the urgent need for targeted interventions to address their socio-economic needs effectively. Additionally, the survey responses underscore the importance of enhancing the effectiveness and inclusivity of adaptation and mitigation strategies to combat desertification in Niger State. While some strategies are currently being implemented, there is a clear need for greater community involvement, policy support, and integrated approaches to enhance resilience and promote sustainable land management practices. Addressing these challenges will require coordinated efforts from various stakeholders to ensure the long-term sustainability and resilience of ecosystems and communities in Niger State and beyond.

Based on the findings and discussions presented in this analysis, the following recommendations are proposed:

i. Governments should develop land-use planning strategies that prioritize sustainable forestry practices and conservation efforts to mitigate deforestation, overgrazing, and land degradation. Additionally, promote soil conservation practices and sustainable agricultural techniques to enhance land management and minimize the adverse effects of poor land management practices on desertification.
ii. Enhance biodiversity conservation efforts through protected area management, habitat restoration projects, and public awareness campaigns aimed at preserving ecosystem services and biodiversity.
iii. Foster collaboration and partnerships among government agencies, NGOs, local communities, and other stakeholders to develop and implement comprehensive adaptation and mitigation strategies that addresses desertification.

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HOUSEHOLDS' CHALLENGES AND COPING STRATEGIES IN WASTE MANAGEMENT IN NSUKKA URBAN AREAS DURING COVID-19 PANDEMIC LOCKDOWN

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ABSTRACT

The concern of this paper is to examine households' challenges and coping strategies in waste management in Nsukka Urban areas during the Covid-19 pandemic lockdown. The population of study is made up of households in Nsukka urban and random sampling techniques were used to select households from seven towns in Nsukka urban areas. It was observed that households in the area faced mild difficulties in coping with waste management during the pandemic lockdown. The result revealed that 64 percent of the household adopted burning as a means of disposing their waste, 84 percent resorted to refuse dumping, while 8 percent of the household adopted the strategy of composing waste. Thus, in order for the people to cope with the heaps of undisposed waste 65% (124.8) of the respondents resulted to burning of their wastes. The researchers, therefore, concluded that Covid-19 restriction was responsible for the non-disposal of wastes by the waste management authority which forced the people into waste burning. Thus, it is recommended that waste management must be a critical component of disease control since solid wastes contain infectious materials that can escalate the spread of the disease in question.

***Key words**: waste management, Covid-19, Nsukka urban*

INTRODUCTION

Issues of environmental pollution have been a major concern to policy makers due to its role in sustainable environment and human development. This is why 3, out of the 17 social development goals is targeted at the environment. They include Goal 6: clean water and sanitation Goal 11: sustainable communities and cities Goal 13: climate action. This is because a healthy environment is important in ensuring sustainable environment (Morrissey & Browne, 2004). Various studies including (Gana and Ngoro, 2014; Pham, Huynh, & Nasir, 2020; Ganivet, 2020; Edeme & Ekene, 2021) reveal that increase in human population and urbanization are accompanied by increase in consumption, which in turn increases waste generation. While wastes are generated in diverse form such as solid, liquid, sludge and gases, there has been a dreadful pollution of the environment (Rahman et al., 2019; Nathaniel & Khan, 2020; Khan, et al., 2022).

In the wake of the covid-19 global pandemic, no economy was immune to its devastating effects. However, while there are some areas in which the pandemic affects every economy, specific to the goal of the study is the challenges the pandemic created for waste management by households. In spite of the fact that the government placed high value on waste collection, the ability to curb waste collection problems deteriorates with time, especially in emerging urban areas.In spite of the fact that globalization ushered in increasingly integrated economic system, Tamazian et al., (2009) notes that financial development has the tendency to harm environmental quality irrespective of development.

Worst still, the Covid pandemic created some challenges for waste management in Nsukka. For instance, there were issues of non-availability of dump site. Also most households found it challenging to package their waste. This study examines the general features of the existing waste management, household challenges and coping strategies in waste management in Nsukka urban during covid-19 pandemic lockdown.

LITERATURE REVIEW

Mian, et al (2017) emphasizes the role of rapid urbanization and economic growth in contributing to waste generation. GDP per capita, population density and educational level also affect solid waste disposal in China. Emelia (2016) found that environmental degradation is linked to poverty. To reduce the rate of environmental degradation, Aiyetan & Olomola, (2017) suggested an increase environmental taxation. In a study of 93 countries, Bao, Anqing, & Weizhong, (2005) show that population growth is a major behind increasing carbon dioxide emissions worldwide. Sulaiman & Abdul-Rahim, (2018) confirm that population growth, economic growth, and energy consumption, were significant in causing degradation. The study by Ohlan (2015) revealed that population density, economic growth, and energy consumption have significant positive impact on CO_2 emissions in both long-and short-run in India. Adusah-Poku, (2016) confirmed that increase in both urbanization and population significantly increases CO_2 emissions both in the long and short run in Nigeria and Ethiopia between 1990 to 2010. For seven East African countries (EACs) Namahoro, et al (2021) revealed that economic and population growth positively affect environmental quality through CO_2 emissions. In western Europe, Weber & Sciubba, (2019) found that increase in regional population growth and urban land use increases carbon dioxide (CO_2) emissions, Alzamora & Barros, (2020) confirmed that lack of finance remains a strong reason why developing economies are struggling with waste management. Ogbonna, Ekweozor, & Igwe, (2002) indicates that growing populations, rising incomes, and changing consumption patterns combine to complicate solid-waste problems in Nigeria is a concern that requires extreme measures to curb.

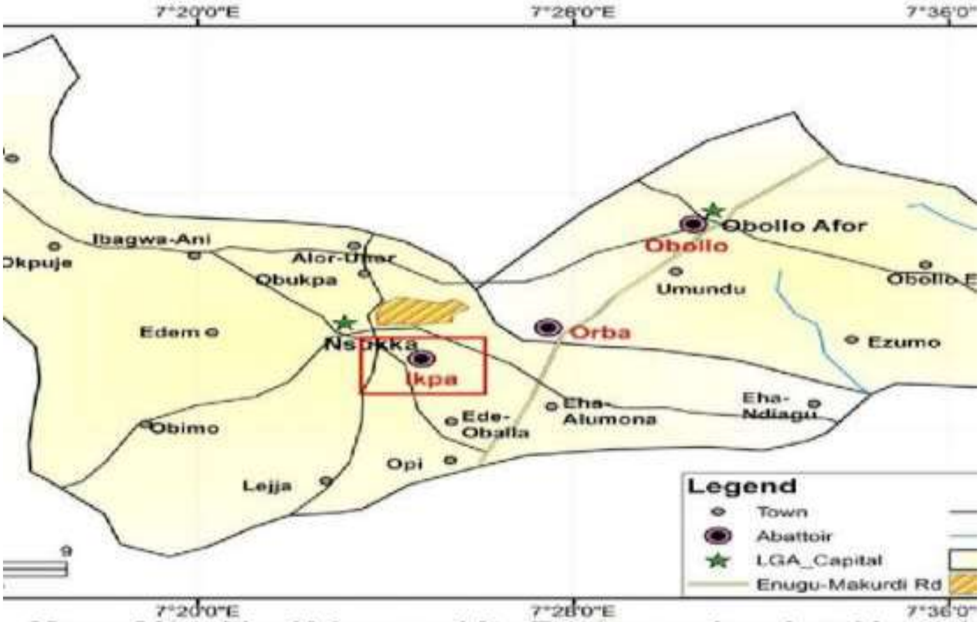
METHODOLOGY

Design of the Study

This study employed descriptive survey design. The essence of this is to understudy the challenges of waste management and the coping strategies by households in Nsukka Urban during Covid 19 pandemic lockdown

Area of Study

This study covers Nsukka Urban area. The area is densely populated due to the presence of notable institutions and organizationssuch as banks, academic institutions, companies and notable markets. According the 2006 census, the area holds a population of 309,633 (NPC, 2022), It is a developing urban centre with several economic activities. The major communities that make up the urban area are Edem Ani, Ibagwa Ani, Opi, Orba, Obimo, Iha-Alumona and Ede Oballa.



Map of Nsukka Urban and Its Environs showing Abattoi

Various households were studied in this area. Waste disposal is markedly a household phenomenon.As a result, the research was restricted to households. The study area is very peculiar for several reasons. Being an urban area, it islargely affected by all the non-pharmaceutical Covid 19 protocols. During the period of lockdown, movements were restricted and work places and business premises were shutdown. Thus, residents within the study area were compelled to stay at home. This isfundamentally why the study was narrowed to households. For the purpose of this study, 160 households were selected as follows: Edem Ani, 25(15.7%), Ibagwa Ani, 25 (15.7%), Opi, 20 (12.6%), Orba, 19(11.9%), Obimo, 21(13.2%), Eha-Alumona while 23(14.5%) Ede Oballa

Method of Data Collection

Data was collected with structured questionnaire. A total of 210 questionnaires were administered within the study area. 30 questionnaires were administered to each of the 7 communities within the urban. A total of 18 questions were asked; covering socio-demographic components of the study area, challenges of waste management and the coping strategies.

Model Specification

Crosstabs was used to estimate the values of research parameters. Crosstabs are used to create contingency table which describe the interaction amongst categorical variables. It uses frequencies and percentages describe to the nature and characteristics of a given population.

Table 1: Contingency Table

	Column 1	Column 2	Column n^{th}	Row Total
Row 1	a	b	n_{1n}	$a+b+\ldots n_{1n}$
Row 2	c	d	n_{2n}	$c+d+\ldots n_{2n}$
Row n^{th}	n_{31}	n_{22}	n_{3n}	$n_{31}+n_{22}+n_{3n}$

Here, Row 1= Edem Ani, Row 2 = Ibagwa Ani, Row n_{th} = Ede Oballa
Columns = each one of the options in the questionnaire
a, b, c, d, nth = observations

RESULT AND DISCUSSIONS

Socio-demographic Characteristics of Respondents

This section presents the socio-demographic characteristics such as gender and place of residence of the respondents. 210 questionnaires were distributed within the study area, that is 30 questionnaires per community. However, 199 questionnaires were returned. Thus, our analysis depends on the information collated.

Table 2: Distribution of the respondents by gender

Gender	Frequency	Percent (%)
Female	81	42
Male	111	58
Total	192	100

Source: Field survey 2022

Table 1 shows the categories of respondents who were involved in the study by sex. It is revealed from the figure that out of the 210 respondents 81(42%) were female where 111(58) were male.

Table 3: Distribution of the respondents by communities

Community	Frequency	Percent (%)
Edem Ani	24	12.5
Ibagwa Ani	25	13
Opi	30	15.6
Orba	28	14.6
Obimo	28	14.6
Eha-Alumona	27	14
Ede Oballa	30	15.6
Total	192	100

Source: Field survey 2022

Table 3 depicts the distribution of the respondents by their place of residence. from the 210 questionnaires that were distributed, the residence of the 192 respondents that returned their questionnaires is given in the table above. The data shows that 24(12.5%) are from Edem Ani, 25(13%) of the respondents are from Ibagwa Ani, 30 (15.6%) are from Opi, 28 (14.6%) are from Orba, 28(14.6%) are from Obimo, 27(14%) are from Eha-Alumona while 30(15.6%) are from Ede Oballa. There is a relative even distribution of the respondents across the communities.

Challenges of Waste Management in Nsukka Urban

Table 4: Major challenge with waste management during Covid-19 Lockdown

Area	Major challenge with waste management during Covid-19			
	Packaging	Disposal	Evacuation	Others
Edem Ani	7 (29.2%)	5 (20.8%)	1 (4.2%%)	11 (45.8%)
Ibagwa Ani	9 (36%)	6 (24%)	3 (12%)	7 (28%)
Opi	2 (8.3%)	7 (29.2%)	13 (54.2%)	2 (8.3%)
Orba	6 (30%)	2 (10%)	0 (0%)	12 (60%)
Obimo	1 (5.3%)	1 (5.3%)	0 (0%)	17 (89.5%)
Eha-Alumona	8 (40%)	3 (15%)	0 (0%)	9 (45%)
Ede-Oballa	2 (8.7%)	1 (4.3%)	20 (87%)	0 (0%)

$X^2 = 118.9$ df = 18

Source: Authors computation

In Table 4, the cross tabulation result indicate that residents of Nsukka Urban had different challenges in waste management during Covid-19 lockdown. In Ibagwa Ani 9(36%) of the householdhad problem with packaging solid waste. In Opi 13(54.2%) of the household were confronted with the problem of evacuation while 20(87%) of the household in Ede-Oballa could not evacuate solid waste during Covid-19 lockdown.

In the same vein, it was found that waste disposal cost next to nothing within the study area. Greater number of the household bore no cost in disposing of waste during the Covid-19 lockdown. As visualized in Figure 1, 75.3% did not pay a dime to dispose waste during Covid-19 lockdown. 12% spent between N100-N500, 9.5% spent between N600-N1000, 1.3% spent N1100-N1500 and above N2000 respectively.

Coping Strategy

Table 6: Residence*How did you dispose waste during Covid?

	How did you dispose waste during Covid Total			
	Burning	Refuse dump	composting	Pooled
Edem Ani	16 (66.7%)	6 (25%)	2 (8.3%)	24(100%)
Ibagwa Ani	17 (68%)	7 (28%)	1 (4%)	25 (100%)
Opi	11 (44%)	13 (52%)	1 (4%)	25 (100%)
Orba	1 (5%)	18 (90%)	1 (5%)	20 (100%)
Obimo	0 (0%)	19 (100%)	0 (0%)	19 (100%)
Eha-Alumona	4 (20%)	16 (80%)	0 (0%)	20 (100%)
Ede-Oballa	15 (65.2%)	5 (21.7%)	3 (13%)	23 (100%)

$X^2 = 59.44$ df = 12

In indicated in Table 6, most households (66.7%) in Edem Ani and Ibagwa (69%) burnt waste during Covid-19 lockdown. At Opi, 13% of the households dropped waste at the refuse dump while a sizeable portion of them burnt refuse. Households in Orba largely disposed waste at the refuse dump. The entire Obimo used refused dumps to discard waste during Covid-19 lockdown. 80% of Eha-Alumona hosehold disposed refuse at the refuse dump. At Ede-Oballa, a greater proportion of the respondents burnt waste. Generally, few persons composted solid waste in the study area.

CONCLUSION

This study analyzed the challenges and coping strategies of households in Nsukka urban areas in managing waste during the COVID-19 lockdown. From the analysis, it was observed that households in the area faced mild difficulties in coping with waste management during the lockdown. The data revealed that of the sampled population, 64% adopted the strategy of burning as a means of disposing their waste, 84% of the households resorted to the strategy of refuse dumping, while relatively small percentage, 8% of households adopted the strategy of composing their waste. This data highlights the need for increased awareness and education on sustainable waste management practices as well as the provision of necessary infrastructure and resources to support these practices in the area. Furthermore, it was observed that demographic, economic, and cultural factors do not pose significant challenges or obstacles in regards to people's preference of coping strategies in the area. However, the fear of getting infected remained the only factor challenging people's willingness to comply with waste management services in Nsukka urban during Covid-19 lockdown.

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A REVIEW OF STUDIES IN LIFE CYCLE ASSESSMENT OF PETROLEUM REFINERIES

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ABSTRACT

The multidisciplinary nature of life cycle assessment (LCA) studies tends to put the researcher in a dilemma of adopting a suitable approach for a particular study. Perhaps, the foremost difficulty is deciding if the assessment is to focus on the product, the process of production, or both a decision that invariably determines the goal and scope of the study. There is also the problem of choosing the impact areas to be considered and the type of data that is appropriate. This study is a systematic review of scholarly publications in LCA studies in the refining of petroleum. The selected journals were from a list returned by a literature search on Google Scholar using the keywords “Life Cycle Assessment," "Petroleum Refining,". Chronologically, preference was given to more recent publications in the selection process. The papers reviewed were process-based and product-based assessments. The scope of studies that were process-based is defined as “well-to-tank” and those that are product-based were either defined as “well-to-wheel” or “well-to-propeller” depending on whether the vehicle is land-based or sea-going. The impact areas considered were mainly environmental, but one study on Life Cycle Sustainability Assessment (LCSA) examined the social aspects with some data modifications. Secondary data and functional units were used for most of the studies, but primary data were collected in some others. The study observed that complexity in LCA research arises from the broadness of scope and wideness of impact areas considered. Ambiguities associated with studies of this nature can be minimized by considering product and process LCA in separate studies, that is, one study can consider “well-to-tank” while another considers “Tank-to-wheel”.

INTRODUCTION

The need for responsible production and consumption (Küfeoğlu, 2022) as captured in the United Nations' sustainable development goals (SDGs) underscores the importance of accountability in the use of natural resources and is a call to users of environmental goods and services to keep track of the direct and indirect impacts of their operational activities. One way to answer this call is to take a quantitative account of resource inputs at every phase of a production process and the waste generated alongside. It is also important to determine the externalities associated with the final product after it is released into the pool of the consumer`s market, and a scholarly approach to achieving this objective is by conducting a life cycle assessment (LCA) of both the production process and the product.

In LCA studies, the inventory of materials and energy deployed in the supply and value chain of a product, process, or service delivery is taken and the cost to the environment is determined. It is a complex study that encompasses a multidisciplinary level of research. The Flexibility of LCA studies allows for its application across industries and organizations, what is peradventure most interesting about LCA is that although it is complex in nature, it can be simplified. It is necessary to ensure caution against oversimplification as this may distort the final result of the Assessment.

Currently, as the world struggles to reach carbon-neutral (Maurya et al., 2021) production, it is required that every identified source of CO2 emission is either discouraged or managed for the least carbon footprint. The petroleum industry is no doubt a major contributor to global greenhouse gas emissions, Grasso (2019) estimated a two-third contribution of the oil and gas industry to climate change, but the industry is nonetheless at the moment an indispensable source of energy (McCabe, 2012, 2020). This a fact that we hope will change shortly (Heidari et al., 2022) for the good of everyone, however, the objective at present is to ensure that the sector's contribution to climate change is generally reduced, and to achieve this, it is important to conduct assessment studies such as LCA for better understanding of processes and their effectiveness.

This study is a systematic review of previous research in the Life cycle assessment of petroleum refineries, to identify the methodologies employed, gaps, and the challenges associated with LCA studies of this nature.

METHODOLOGY

The reviewed literature in this study was selected randomly from the results returned by strategic search on Google Scholar, Science Direct, and Elsevier. Keywords from the title of the study were varied to ensure that the already named journal publishing platforms recommend journals that are relevant to the study. The following combinations of words were entered in the advanced search field (Life cycle OR LCA AND Petroleum AND Refinery).

From the journals returned by the search, chronological preferences were given to the ones selected such that the oldest journal reviewed was published in 2012 and the most recent was published in 2022. Consideration was also made for the geographic spread of the locations where the studies were conducted. Figure 1 captures the chronological and geographical distribution of the reviewed literature. The analysis uses an orderly approach (Al Zarkani et al., 2023) in identifying the aim and scope of each study, the methods adopted, the types of data that were collected and analyzed, and the findings made. This approach will ensure that relevant aspects of all research efforts to be reviewed are considered in the analysis.

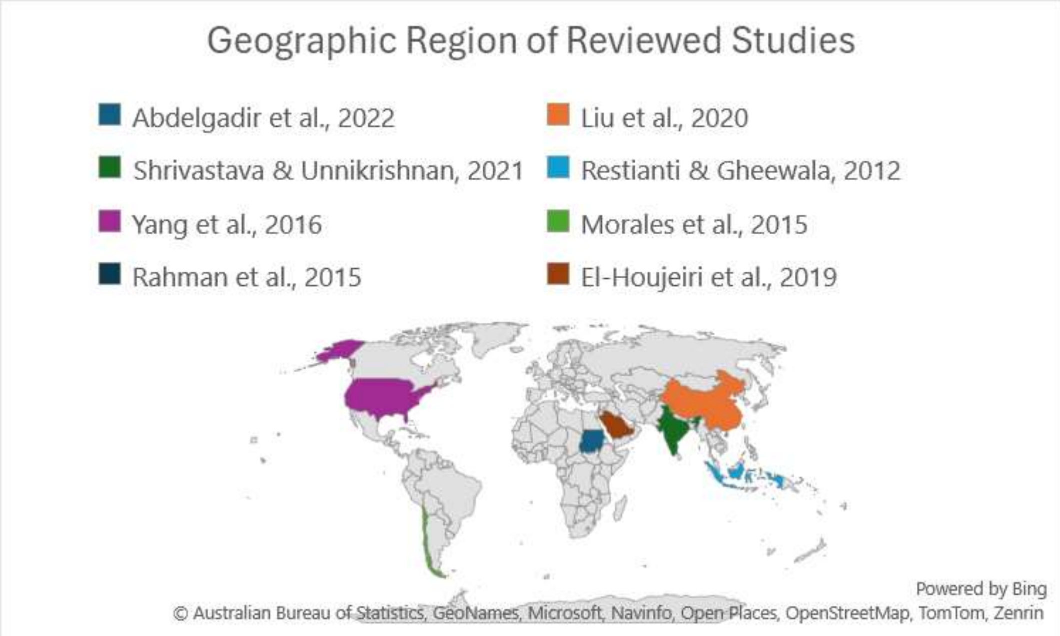

Figure 1: Chronological and Geographical Distribution of the Reviewed Studies

RESULTS AND DISCUSSION

Defining Goal and Scope in LCA of Petroleum Refinery

Deciding the extent to which an LCA study should stretch is probably one of the hard-to-reach decisions for researchers in the field. Nevertheless, goal and scope definition is very important, as it provides a guide as to how the studies should progress. LCA studies are multidisciplinary in nature and a lot of caution needs to be taken to avoid ambiguities.

In the studies reviewed, assessments were in some cases limited to the efficiency of the petroleum refining process for example, Liu et al. (2020) studied the petroleum refining process in China with the intent of identifying room for improvement in environmental performance. Based on resource material, Abdelgadir et al. (2022) compare the impacts of refining two crude oil types in two separate refineries. The scope can also be defined by selected environmental indicators to be investigated Kheiralipour et al. (2021).

Another angle from which the study can be approached is to simply investigate the level of environmental impact associated with the industry and the scope of the study can cover both the process and the product assessment but must be properly defined. Shrivastava and Unnikrishnan (2021) evaluate the life cycle sustainability performance of crude oil at various stages from extraction to the storage of final refined product. This is an example of a production-based assessment starting at the well and terminating at the tank. The studies by Rahman et al. (2015), Morales et al. (2015), and El-Houjeiri et al. (2019) cover the impact assessments of production and product. The scope in Rahman et al. (2015) and Morales et al. (2015) which focused on land-going vehicles, were defined as "well-to-wheel". However, the scope of the study on refined products used in ships by El-Houjeiri et al. (2019) was defined as "well-to-propeller".

Approach to Study

Generally, approaches to studies in LCA have evolved. A chronological overview of the studies reviewed reveals a shift in the methodology adopted by the authors. We observed that assessment was conducted based on the International Organization for Standardization (ISO) standard for studies published in 2016 and below (Morales et al., 2015; Yang et al., 2016). The earliest use of a model amongst the papers consulted, was by Rahman et al. (2015) in which a LCA model called FUNNEL-GHG-CCO (FUNdamental Engineering PrinciplEs-based ModeL for Estimation of GreenHouse Gases in Conventional Crude Oils) was used. Recent studies in LCA are Model-based and the most adopted assessment standard is the ReCiPe method (Abdelgadir et al., 2022; Liu et al., 2020).

Type of Data Used

The main types of data used are primary and secondary input and output quantitative data collected at the refinery either firsthand by inserting a measuring instrument in the pipeline (Liu et al., 2020) or from their records (Restianti & Gheewala, 2012; Shrivastava & Unnikrishnan, 2021). Secondary data sources were from online databases (Yang et al., 2016), literature (El-Houjeiri et al., 2019), and periodical reports. Data on materials and energy consumption were collected and the amount of pollution in the form of gas, liquid, and solid waste from the process was measured.

Key Findings

Reporting of findings is usually in consonance with the aim of the studies. For studies that are impact-based like those of Liu et al. (2020), Kheiralipour et al. (2021), and Restianti and Gheewala (2012), findings were presented concerning environmental impact indicators. Liu et al. (2020) observed that the primary contributors to Ozone Depletion (OD), Human Toxicity (HT), and the generation of photochemical oxidants (POF) in the life cycle of refining processes are the Volatile Organic Compounds (VOCs) produced during on-site refinery operations. Whereas it was discovered by Restianti and Gheewala (2012) that Gasoline combustion is dominantly responsible for global warming potential (GWP), acidification potential (AP), and eutrophication potential (EP), whilst abiotic depletion is dominated by crude oil extraction and the dominant contributor for human toxicity potential and ecotoxicity potential is the refinery stage. In Kheiralipour et al. (2021) it was shown that the highest impact value of the natural gas refinery process was related to fossil abiotic depletion and global warming indicators.

Other studies reveal that The main environmental impact of crude oil refining is because of the use of Heavy Fuel Oils (HFOs) and pipeline is the cleanest mode for transporting refined products (Shrivastava & Unnikrishnan, 2021), Refining of Asphalt binder could have up to a 14% difference in environmental impacts more that of producing diesel fuel (Yang et al., 2016), and that crude oil type also have significant effect on the impact potentials of the process (Abdelgadir et al., 2022; Rahman et al., 2015).

CONCLUSION

We conclude that LCA studies of petroleum refineries are a research field that is still evolving, particularly in the area of deciding the extent to which a single study of such nature should reach. Worthy of note is the study conducted by Shrivastava and Unnikrishnan (2021), which was the only paper reviewed in this study that considered the socio-economic impacts of petroleum refining. Their study adopted a mixed methodology by conducting interviews and administering questionnaires. The responses from responders had to be converted using standards to enable their inclusion in the quantitative analysis. This then begs the question as to the applicability of such standards in every demographic stratum of our heterogeneous global community. Given that LCA studies are generally quantitative in nature (Hauschild et al., 2018), how rational is the combination of quantitative and qualitative data in studies of this kind?

In addition, we noticed that ambiguity arises in studies that have a scope covering the production process and the final product, authors whose scope of assessment was from "Well-to-wheel" tend to depend on secondary data for their analysis. Similarly, regional scale assessment (El-Houjeiri et al., 2019; Yang et al., 2016) should be discouraged as it does not give room for a detailed analysis or localization of findings. Studies of this type should be case-specific, i.e., assessing the operation of a particular refinery (Liu et al., 2020), evaluating the impact of refining a named crude oil type (Abdelgadir et al., 2022), or comparing the impact proportion of petroleum products (Yang et al., 2016). Finally, it is clear that life cycle assessment research in the petroleum refining industry can help to understand the flow of resources in the sector and provide information on strategies for safer and operational approaches.

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ADDITION OF SURFACE-MODIFIED NANOCLAY INTO BROILER FEEDS ADSORBS AFLATOXINS WITHOUT AFFECTING BLOOD PROTEIN & LIPID METABOLITES AND LIVER BIOMAKER ENZYMES

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ABSTRACT

Aflatoxins are toxic secondary metabolites produced by fungi which contaminate livestock feeds and cause serious health problems in broiler chickens. The use of surface-modified nanoclay to mitigate the effects of aflatoxin in poultry feeds has recently gained considerable attention. Consequently, this study was carried out to evaluate the potentials of amino acids-modified nanoclay as adsorbent of aflatoxin in broiler feeds and investigating the effects on blood protein & lipid metabolites, and liver biomarker enzymes. Nanoclay modified with lysine was added into broiler feeds (at 3g/Kg) and aflatoxin corn (at 4000 ng/Kg) to test aflatoxin-adsorption efficiency, and the treatment was labeled as Experimental (EXP). Other treatments included the Control (CNT), containing only the feed; the lysine modified nanoclay (MNC LYS), was added in the feed (at 3g/Kg) and the Aflatoxin Control (AFC), (at 4000 ng/Kg). The treatments and drinking water were fed *ad libitum* to groups of 10-day old chicks (in replicate), respectively for 5 weeks. At the end of the feeding trial, blood samples were collected for analysis. Results of blood biochemical tests and liver function enzymes revealed that addition of amino acid-modified nanoclay has high aflatoxin-adsorption efficiency with significantly effects at $p<0.05$. Addition of modified nanoclay significantly reduced the toxicity of aflatoxins in broiler feed. Experimental broiler blood protein and lipid metabolites were also not significantly affected. Results of the present study suggests that amino acids-modified nanoclay has great potential as adsorbent of aflatoxin in feeds that may help in protecting the health of broiler chickens.

Key words: *Aflatoxin, Nanoclay, Broiler chicken, Poultry feeds, Amino acids*

INTRODUCTION

Aflatoxins are highly toxic secondary metabolites produced by certain fungi, primarily Aspergillus species, commonly found in grain crops.(Adeyeye, 2016) These toxins have been known to contaminate animal feeds, leading to serious health issues in livestock, including decreased feed intake, poor growth performance, immunosuppression, and even mortality. Afsah-Henri, *et al.,* (2013). Therefore, there is a crucial need for effective strategies to mitigate aflatoxin contamination in poultry feeds.

One promising approach is the use of modified nanoclay as a feed additive (Awuor *et al*., 2017). Nanoclays are nanoscale particles composed of layered silicates that have been shown to effectively adsorb aflatoxins due to their high surface area and cation exchange capacity (Chanra *et al*., 2019). However, the potential impacts of modified nanoclay on blood protein and lipid metabolites, as well as liver biomarker enzymes in broiler chickens, have not been thoroughly investigated. This study aims to assess the efficacy of modified nanoclay in adsorbing aflatoxins in broiler feeds while evaluating its potential effects on the metabolic and liver health of the animals.

MATERIALS AND METHODS

In this study, a total of 80 broiler chickens were randomly divided into four groups**:** CNT (group fed with aflatoxin -free feed), MNC-LYS (a group fed with feed containing only modified nanoclay lysine), AFC (a group fed with aflatoxin-contaminated feed at a concentration of 109 mg/g) and EXP (a group fed with aflatoxin-contaminated feed supplemented with modified nanoclay at a concentration of 233mg/g). The chickens were fed for a period of five weeks and blood samples were collected at the end of fifth (5) week for the analysis of liver biomarkers enzymes, protein and lipid metabolites.

RESULT

Table 1 shows results of liver biomarkers of experimental broiler chickens.

Parameters **Treatments**	ALP (U/L)	ALT (U/L)	AST (U/L)
CNT	61.58 ± 0.65^{a}	26.85 ± 0.39^{a}	25.14 ± 0.51^{a}
MNC-LYS	53.17 ± 0.60^{a}	22.12 ± 0.45^{a}	24.77 ± 0.37^{a}
AFC	112.53 ± 0.83^{b}	56.24 ± 0.25^{b}	66.59 ± 3.24^{b}
EXP	70.83 ± 0.22^{a}	24.33 ± 0.41^{a}	30.94 ± 0.16^{a}

Values are presented as mean ± standard error of mean (SEM) of three replicates.
Values with different superscripts in a column are significantly different at ($p < 0.05$)

Table 2 Show result of liver proteins metabolites of experimental broiler chickens

Parameters **Treatments**	ALB	TB	TP
CNT	5.89 ± 0.12^{a}	0.45 ± 0.00^{a}	10.90 ± 0.55^{a}
MNCLYS	6.04 ± 0.07^{a}	0.45 ± 0.01^{a}	12.05 ± 0.20^{a}
AFC	6.52 ± 0.15^{a}	0.59 ± 0.00^{a}	10.98 ± 0.13^{a}
EXP	6.75 ± 0.16^{a}	0.53 ± 0.01^{a}	12.35 ± 0.24^{a}

Values are presented as mean ± standard error of mean (SEM) of three replicates.
Values with different superscripts in a column are significantly different at ($p < 0.05$)

Table 3 Show result of liver lipid of experimental broiler chickens.

Parameters **Treatments**	CHO	HDL	LDL	TRIG
CNT	320.77±0.67^a	59.44±0.41^b	118.58±0.77^a	115.77±0.22^a
MNCLYS	317.67±0.29^a	76.39±0.40^d	101.45±0.39^a	111.40±0.71^a
AFC	431.32±0.57^b	45.14±0.45^a	134.19±0.52^b	271.78±0.48^c
EXP	323.65±0.29^a	65.25±0.34^b	110.46±0.33^a	152.06±0.48^b

Values are presented as mean ± standard error of mean (SEM) of three replicates.
Values with different superscripts in a column are significantly different at ($p < 0.05$).

DISCUSSION

The result of table 1 showed that the addition of modified nanoclay to aflatoxin-contaminated feed significantly reduced the levels of aflatoxins in the feed, as evidenced by lower levels of aflatoxin biomarkers in the blood of the treated group compared to the untreated group. Asrani, *et al.,* (2019). Importantly, the supplementation of modified nanoclay did not lead to any significant changes in the levels of blood protein and lipid metabolites, indicating that the additive had no adverse effects on the metabolic health of the broiler chickens (Wu, 2015). Furthermore, the activities of liver biomarker enzymes were within normal ranges in the treated group, suggesting that the modified nanoclay did not induce any hepatotoxic effects in the animals. Because liver biomarker enzyme of broiler chickens fed with CNT feed are within the normal physiological ranges (Rushing *et al.,* 2019). investigated the effect of different feed protein level on blood biochemistry in broiler chickens.The study found no significant changes in the levels of liver biomarkers enzyme in the broiler chickens fed with CNT feeds. Similarly, there was decrease in liver biomarkers enzymes of broilers fed with MNC-LYS feeds a study by Wang, *et al.,* (2020).

Incorporated modified nanoclay in to broilers feed and evaluated its effect on liver biomarker enzymes, which show that modified nanoclay had no adverse effects on liver. In AFC there was high increase of liver biomarkers enzymes in broiler chicken blood sample which signifies liver damage. Moretti, *et al.,* (2019) examined the effects of Aflatoxin contaminated feed on liver biomarkers enzymes in broiler chickens. Which report that feeding broilers with Aflatoxin significantly increased the activities of liver biomarkers enzymes, indicating liver damage. In EXP treatment there was decreased in liver biomarker enzymes which show the potential of modified nanoclay in adsorbing aflatoxin from the feeds which prevent aflatoxin from damaging the liver of the broiler chickens. Matumba, *et al.,* (2019) investigated the potential protective effect of modified nanoclay against Aflatoxin -induced liver damage in broilers. And the study shows that inclusion of modified nanoclay in Aflatoxin-contaminated feed helped to mitigate the liver damage and inflammations caused by Aflatoxin.

Table 2 result showed that broiler chickens fed with CNT, MNC-LYS and EXP feed found to have increased level of liver protein metabolites (ALB) in blood of broiler chickens and decreased level of liver protein metabolites (TB) in the blood, similarly attend normal range level of TP in the blood. Consequently, AFC show a very low level of ALB in the blood of broiler chicken and very high level of TB in the blood. TP appeared to be low in AFC. With this level of ALB and TB it showed that aflatoxin has cause liver damage to the broilers that fed on AFC feed. Which this study is in line with Marchese, *et al.,* (2018) investigated the impact of aflatoxin in liver protein metabolites in chickens. The findings state that broilers fed with AFC exhibited significantly decreased level of ALB compared to CNT. Moreover, elevated levels of TB and reduced TP level were observed in AFC, indicating liver dysfunction. In EXP, MNC-LYS and CNT higher level of ALB, reduced level of TB and increased level of TP were observed indicating a protective effect of liver protein metabolites compared to AFC.

The result showed in table 3 indicate the liver lipids CHO, HDL, LDL and TRIG level in broiler chickens of all the treatments. The broiler chickens fed with CNT, MNC-LYS and EXP feed showed a significant decrease in CHO, LDL and TRIG in broiler chicken when compared to AFC treatment. In CNT, MNC-LYS and EXP, it showed a significant decreased in HDL Li, *et al.,* (2018) investigated the impact of feed containing modified nanoclay on lipid metabolism in broiler chickens. The result showed a very low level of HDL in AFC.This suggests that modified nanoclay might have a beneficial effect on liver lipid metabolism in broiler chickens and aflatoxin, indicating an impaired lipid metabolism (Kew, *et al.,* 2013)

CONCLUSION AND RECOMMENDATION

In conclusion, the addition of modified nanoclay into broiler feeds effectively adsorbed aflatoxins without affecting blood protein and lipid metabolites, as well as liver biomarker enzymes in broiler chickens. These findings highlight the potential of modified nanoclay as a safe and efficient strategy for mitigating aflatoxin contamination in poultry feeds, thereby enhancing the health and performance of broiler chickens. Further studies are warranted to elucidate the long-term effects of modified nanoclay supplementation and optimize its application in commercial poultry production.

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POLICY REVIEW OF E-WASTE AS A RENEWABLE RESOURCE FOR ENVIRONMENTAL STABILITY: INSIGHTS FROM AFRICA

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ABSTRACT

The management of electronic waste (e-waste) is a pressing global issue with significant implications for environmental sustainability. A comprehensive policy review that explores the potential of e-waste as a renewable resource for promoting environmental stability, with a specific focus on insights from Africa is presented. In 2019, an estimated 54 million metric tons of e-waste were produced globally while Africa generated an estimated 5.8 to 3.4 million metric tons of e-waste, highlighting the region's growing challenge in managing electronic waste. Despite this, African nations are making strides in addressing e-waste issues through initiatives such as Ghana's e-waste eco-levy and South Africa's Producer Responsibility Organization (PRO) model. However, as of 2019, only 13 African countries had national legislation governing e-waste disposal, indicating the need for stronger regulatory frameworks and enforcement mechanisms. Challenges such as lack of uniform regulations for standardization, ineffective policies, poor adherence to laws and weak enforcement contribute to high levels of toxicants in some African regions. To address these deficits, the "Best of Two Worlds (Bo2W)" philosophy is proposed as a solution approach for managing e-waste in African countries. By integrating sustainable practices, circular economy principles, and innovative strategies like consumer motivation and involvement, and extended producer responsibility (EPR) schemes, Africa can harness the potential of e-waste as a valuable resource while minimizing its environmental impact. This policy review underscores the importance of collaboration among stakeholders, transparent governance structures, and capacity building to achieve long-term environmental stability and resource efficiency in the management of e-waste in Africa.

Key words: *Electronic waste, Disposal, Regulations, Sustainable practices, Review*

INTRODUCTION

The rapid advancement of technology and increased use of electronic devices have led to a critical global concern: electronic waste (e-waste). The e-waste includes discarded electrical and electronic equipment (EEE) and its components, contributing to environmental and health risks (Oteng-Ababio *et al*., 2020). In Africa, urbanization, and economic growth fuel the demand for electronic devices, exacerbating e-waste generation, often from imported devices losing value quickly (Maes, and Preston-Whyte, 2022). While some progress has been made in enacting regulations and establishing infrastructure, many countries still lack comprehensive solutions. Holistic approaches involving governments, industry stakeholders, academia, and civil society are crucial, with a focus on community engagement, public awareness, and environmental justice. Advances in recycling technologies offer opportunities for resource recovery and a circular economy (Oteng-Ababio *et al*., 2020). The review aims to inform policy decisions and inspire collective action toward sustainable e-waste management in Africa.

METHODS

Various search engines were explored using keywords such as e-waste management, eco-levy Producer Responsibility Organization (PRO) system, legislation, Best of Two Worlds" (Bo2W) philosophy.

DISCUSSION

Current Status of E-waste in Africa

According to the 2016 Global E-waste Monitor, 44.7 million tons (Mt) of e-waste were produced globally, with only 20% recycled through approved means, and only 41 nations recorded statistics on e-waste (Baldé *et al*., 2017). Africa produces significantly less e-waste than Europe and the Americas combined, with an average yearly per capita production of 2.5 kg. The estimated global amount of e-waste in 2030 is projected to be 74.7 Mt, indicating a 36.3% increase in consumption (Baldé *et al*., 2017; Forti *et al*., 2020). It was reported that between 50% and 85% of Africa's total e-waste is produced locally, with the remainder from unauthorized trans-boundary imports (Manhart *et al*., 2011). In 2019, Africa produced 2.9 Mt of e-waste, with Egypt, South Africa, and Nigeria leading in production. Algeria, Botswana, Gabon, Namibia, and Libya have the highest per capita generation rates. Estimates suggest Africa's e-waste volumes to be between 5.8 and 3.4 Mt, though considered underestimated (Maes and Preston-Whyte, 2022).

1. E-Waste Management in Africa

Globally, in 2022, approximately 62 billion kilograms of e-waste were generated, averaging 7.8 kilograms per capita, with only 22.3% formally collected and recycled in an environmentally sound manner. Since 2010, e-waste generation has outpaced formal collection and recycling by nearly fivefold (Cornelis *et al*., 2024). In Africa, e-waste management involves dismantling for e-scraps through processes like collection, segregation, cleaning, size reduction, and recycling. Quality second-hand electrical products are refurbished or repaired and sold as refurb products, while various companies, including international Technology Group, Recycle Bekia, and Eco Integrated Industrial Systems, are involved in e-waste recycling (Moyen and, Archodoulaki, 2023). However, the informal sector dominates, recycling for metal recovery. Some countries like South Africa, Egypt, Morocco, Namibia, and Rwanda have legitimate e-waste recycling industries supported by the informal sector, while in Ghana and Nigeria, the informal sector solely drives e-waste industries. In places like Agbogbloshie, Ghana, informal e-waste recycling has become vertically integrated into a functioning e-waste economy (Amankwaa, *et al*., 2017).

2. Challenges Faced by African Nations in Managing E-waste Effectively

The development of e-waste in Africa stems from various factors, including technological advancements, socioeconomic factors, and policy deficiencies (Daum *et al*., 2017). Inadequate legislative frameworks and enforcement mechanisms lead to ineffective management practices, such as informal recycling, posing health and environmental risks. Many African nations lack sufficient recycling infrastructure and environmental regulations, resulting in improper disposal of electronic devices (Mohee and, Simelane, 2015). Limited awareness about the hazards of e-waste exacerbates the problem. Rapid industrialization and urbanization increase the demand for electronic gadgets, while the importation of used electronics from wealthier nations adds to e-waste volumes (Işıldar *et al*., 2018; Singh *et al*., 2018). Understanding these factors is crucial for developing effective solutions to Africa's e-waste management challenges.

3. Existing Policy Initiatives of E-waste management in Ghana and South Africa

In 2018, Ghana introduced the Hazardous and Electronic Waste Control and Management Act 917, along with the Eco-Levy, to regulate electrical and electronic equipment (EEE) imports (Canavati, *et al*., 2022). The legislation aims to manage waste disposal by requiring producers and importers to register and pay an upfront eco-levy. Funds collected support implementation and formalization of recycling practices, while prohibiting hazardous materials' transportation and sale (Forti *et al*., 2020). According to the Plastic Revolution Foundation (2022), Ghana seeks to adopt Extended Producer Responsibility (EPR) to further improve e-waste management. Similarly, South Africa's Producer Responsibility Organization (PRO) model aligns with EPR principles, enhancing e-waste management by mandating producers to finance collection and recycling programs (Take-Back, 2023). Despite success in increasing recycling rates and reducing environmental impact, challenges like informal recycling and regulatory enforcement persist, necessitating continuous monitoring and innovation for sustainable e-waste management.

4. Legislative Frameworks

Several legislative frameworks exist for e-waste management in Africa, with efforts to increase global coverage of e-waste laws. While progress has been made, only 42% of countries have policies, laws, or regulations addressing e-waste as of June 2023, falling short of the 50% target set in 2018 (ITU, 2021). Policymakers face challenges due to the increasing variety of electronic and electrical equipment (EEE), requiring distinct end-of-life treatments and collection approaches (Baldé *et al*., 2017; Huisman *et al*., 2017).

Harmonizing e-waste definitions and registration processes across jurisdictions could enhance tracking and prevent illegal transboundary movement. Extended Producer Responsibility (EPR) systems, although effective, require proper monitoring and administration. However, data availability and accessibility for e-waste management remain weak globally, requiring substantial financial investment for improvement. As of 2019, only 13 African countries had national regulations governing e-waste disposal (OECD, 2019).

5. Environmental Implications of E-waste

Improper disposal of electronic waste (e-waste) poses significant environmental risks, including contamination of soil, water, and air due to toxic substances like lead, mercury, and cadmium (Gupta, 2019). This contamination threatens ecosystems, biodiversity, and human health, leading to respiratory problems, neurological disorders, and reproductive issues. Inefficient e-waste management also contributes to the depletion of natural resources, as valuable materials are not adequately recycled (Awasthi *et al*., 2019). Addressing these challenges requires comprehensive e-waste management strategies, including proper collection, recycling, and disposal practices, alongside policies promoting sustainable consumption and production of electronic devices (Liu *et al*., 2022).

6. Opportunities for Innovation

Innovative technologies and approaches for e-waste recycling and resource recovery offer promising solutions. Robotic dismantling systems automate the dismantling process, enhancing efficiency and safety (Liu *et al*., 2020). Chemical recycling breaks down e-waste materials for efficient recovery of valuable metals, reducing environmental impact (Lederer *et al*., 2021). Biotechnology-based methods like bioleaching and bioremediation extract metals using microorganisms, providing eco-friendly alternatives (Liu *et al*., 2020). Additive manufacturing technologies repurpose e-waste materials into new products, reducing the need for virgin resources and minimizing waste (Torres *et al*., 2020). Successful innovation initiatives include the Agbogbloshie E-Waste Recycling Hub in Ghana, the E-Waste Academy in Nigeria, and the Recycling Electronic Waste for Profit Project in Kenya (Amankwah-Amoah *et al*., 2020; UNEP, 2020).

7. Best of Two Worlds (Bo2W) Philosophy

The "Bo2W" concept promotes environmentally friendly outcomes in developing nations by facilitating the delivery of e-waste fractions to advanced processing facilities globally while enabling local pre-processing through manual dismantling (Wang *et al*., 2012). This approach optimizes material recovery and detoxification, utilizing international processing infrastructure and benefiting from economies of scale. Gmünder, (2007) and Rochat *et al*. (2008), suggest that this strategy can be profitable while minimizing environmental impact and improving environmental care standards in poorer nations. In Africa, sustainable e-waste management involves durable product design, reuse programs, community engagement, integration of the informal sector, advanced recycling technologies, Extended Producer Responsibility (EPR) programs, awareness campaigns, and comprehensive policy frameworks. These practices aim to reduce pollution, conserve resources, create jobs, and promote sustainable development.

Role of Collaboration and Governance

Collaboration between governments, industries, and other stakeholders is crucial for developing comprehensive e-waste management strategies and policies. Multi-stakeholder collaboration is essential for addressing the complex challenges associated with e-waste generation, disposal, and recycling (Huisman and Stevels, 2019). Transparent governance structures and enforcement mechanisms are necessary to ensure compliance with e-waste management regulations and hold stakeholders accountable for their responsibilities (OECD, 2019; UNEP, 2019).

Capacity Building for Sustainable E-waste Management

Building capacity among stakeholders is crucial for promoting sustainable e-waste management practices. Training programs and capacity-building initiatives are essential for raising awareness, building technical expertise, and promoting best practices (Huisman and Stevels, 2019). Education and training programs targeting consumers, businesses, and policymakers are crucial for promoting responsible e-waste management practices (OECD, 2019). Community-based education initiatives can engage local communities in e-waste management efforts, empowering them to participate in sustainable waste management practices (UNEP, 2019). Government-funded initiatives, industry partnerships, and international organizations can provide technical assistance, training, and resources to support capacity-building efforts and strengthen e-waste management infrastructure (UNEP, 2019; Amankwah-Amoah *et al*., 2020).

CONCLUSION

Effective management of e-waste presents a global challenge with significant environmental and socioeconomic implications. By implementing the recommendations outlined below, stakeholders can work collaboratively to address the complexities of e-waste management and transition towards more sustainable practices. Enacting comprehensive policies, fostering innovation, promoting collaboration, building capacity, engaging communities, and strengthening international cooperation are essential steps towards mitigating the environmental impact of e-waste and promoting a circular economy approach. With concerted efforts and collective action, we can achieve long-term environmental sustainability and create a more resilient and inclusive society for future generations.

RECOMMENDATIONS

To manage e-waste effectively, policymakers and stakeholders should prioritize the enactment and enforcement of comprehensive e-waste management laws, integrating extended producer responsibility and eco-design principles. Investment in research and collaboration is crucial to develop cost-effective and scalable e-waste recycling technologies, fostering partnerships between government, industry, and research institutions. Multi-stakeholder collaboration and transparent governance structures are essential to facilitate coordination and oversight. Education and training programs should be implemented to raise awareness and build technical expertise among stakeholders, including vocational training for e-waste collection and recycling. Empowering local communities through engagement initiatives and fostering international cooperation for knowledge exchange and capacity-building efforts can further advance sustainable e-waste management practices globally.

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THE EFFECTS OF SOCIAL VICES ON ENVIRONMENTAL HEALTH AND QUALITY OF LIFE IN NGENEVU URBAN SLUM DWELLERS IN ENUGU STATE

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ABSTRACT

Slums in cities are a global issue that has sparked debate among agencies and governments worldwide, particularly in Sub-Saharan Africa. Quality of life is also an essential measure in the assessment of citizens' well-being and health status. Attaining a high quality of life has been the inherent aim of public policy in almost every society for many centuries**.** This study was motivated by the deluge of social vices and poor quality of life witnessed in this slum. Dependency theory was used for the study. A descriptive survey was used as the research design.40 respondents, who are 18 years of age and older and are slum residents, were selected from the four zones that made up the community used for the study. For data collection, qualitative data was employed through key informant interviews, in-depth interviews, and focus group discussions. The data generated was transcribed, and the presentation of the data was descriptive. Findings from the study show that social vices in urban slums have an effect on their living conditions. The study also showed that social vices have serious effects on the quality of life of slum dwellers. However, the study concludes that more efforts should be put in place to prevent immoral behavior in the slum areas. Based on the following results, this study suggests that the government should pay greater attention to the difficulties faced by slum residents in order to bring sanity to the slum areas.

***Key words**: slums, quality of life, social vices, Ngenevu, Nigeria.*

INTRODUCTION

Slums are urban areas that are densely populated and characterized by poor living conditions. They lack basic services such as running water, electricity, and sanitation. Slums also have poor infrastructure, like streets that are unpaved or not properly maintained. In addition, housing in slum areas is often overcrowded, with many people living in small spaces. There is also often a lack of green space or outdoor areas to relax in. This condition is a global issue of concern that has been a major topic of discussion for agencies and governments across the globe, mostly in sub-Saharan Africa. According to UN Habitat's 2019 report, there will be 2 billion people living in urban areas by 2030, and by 2050, that number will have increased by 70%. In the same vein, 69 percent of Nigeria's urban population lives in slums, according to UN-Habitat Habitat's Country

Programme document for 2017 to 2021. Hardiman and Midgley (1982) identified some negative effects of urbanization and explained the need for planning and efficient urban management to address problems such as urban violence, poor access to necessary infrastructure and services, a lack of adequate housing, homelessness, erratic sprawl of economic activity in public spaces, and poverty. Slums are common international phenomenon that are found in practically all cities and towns in Nigeria, and they are characterized by a concentration of poor urban housing and squalor (Ayuba 2019, Ekpeyong, and Mathias, 2019). Urban centers experience an increase in crime, violence, and lawlessness due to the havens for criminal activity and other social vices found in slums (Ekpeyong and Mathias, 2019). According to Buhaug and Urdal (2013), the slums are the primary source of social and political turmoil in urban areas.

On the other hand, the World Health Organization (WHO) (1998) defines quality of life as "an individual's perception of their position in life in the context of the culture and value systems in which they live and in relation to their goals, expectations, standards, and concerns. Living conditions in slum areas are frequently appalling. Generally speaking, slum dwellers don't have access to essential amenities such as sanitary conditions, medical treatment, clean water, etc. They may also have to live in unsafe and unhealthy conditions, with little privacy or personal space. There is often a lack of employment opportunities and educational resources in slum areas. For many centuries, attaining a high quality of life has been the aim of public policy in almost every society. Consequently, for the effectiveness and efficiency of quality of life aimed at eradicating social vices in urban slums in Nigeria, there is a need to capture the silently growing urban slums. This study therefore intends to explore the effects of social vices on environmental health and quality of life among Ngenevu urban slum dwellers in Enugu State.

Statement of the Problem

The absence of human and social needs-focused urban planning and administration poses significant hurdles to improving people's satisfaction and quality of life. Since a large portion of the population lives in slums and poverty rates are high, quality of life has become a major concern in these areas. The absence of authorized government recognition in these locations causes several social, environmental, and political exclusions that negatively impact citizens' health. People usually reside in inadequate housing and are involved in a plethora of activities, indiscriminate refuse disposal and the ensuing damage to the environment due to environmental unawareness with regard to slum improvement.

Objectives of the Study:

The following are the objectives of the study:

i. To identify the most common types of social vices in the Ngnevu urban slum.
ii. To assess the effects of social vices on physical, mental, and emotional health among slum dwellers.

iii. To develop a list of evidence-based strategies for addressing social vices in the slum area.

METHODOLOGY

The study was conducted in Ngenevu, Enugu State, Nigeria. The Ngenevu community comprises four zones, namely zones A, B, C, and D. Ngenevu served as an ad hoc community that emerged around the coal camp in Enugu. It is topographically constrained. For the study, both primary and secondary data were used.A descriptive survey was used as the research design. 40 participants, who were all 18 years older and slum residents, were drawn from the four zones that make up the study. For data collection, qualitative data was employed, namely, in-depth interviews, focus group discussions, and key informant interviews. In-depth interviews were conducted with some individuals living in the slum community to gain a deeper understanding of how social vices affect their lives. Key informant interviews were also conducted with slum dwellers who have firsthand knowledge of the community. A focus group was carried out on the slum residents to explore how they perceive and experience social vices. The participants consisted of 6–8 members. This was also to prevent overcrowding. The secondary data were obtained mainly from books, journals, and the internet. The qualitative data was explained through thematic analysis.

EMPIRICAL REVIEW

In recent years, an increasing number of studies on urban slum dwellers have been carried out in various countries around the world.

The social vices in the slum of Kăsùwăr Rûwà and their effects on sociopolitical activities in the Lokoja Metropolis were examined by Bature (2021). The relative deprivation theory served as the study's foundation. To collect data, primary and secondary sources were adopted. Descriptive statistics were used in the data analysis process. Based on the analysis's findings, the study recommended that all parties involved in Lokoja, including those from traditional, political, and security institutions, make a strong commitment to battling the slum's threat, with a focus on enforcing strict adherence to the rules of behavior in all interactions with residents. Although this study is helpful, it does not demonstrate the type of analysis that was employed for data analysis.

Wajim J. Garba, D. Shimfe, and Grace (2021) explored Nigerian urbanization and its social vices. This study looked at Nigerian urbanization and associated social vices. Urbanization is the process by which people move from rural to urban areas and the gradual rise in the percentage of people who live in urban areas. The author emphasized that environmental problems, unemployment and poverty, and crime and insecurity are some of the social vices associated with urbanization in Nigeria. Secondary data collection methods were employed in the study. In light of the study's conclusions, it is advised that, in order to prevent rural inhabitants from migrating in large numbers to urban areas, the government should pay more attention to the socioeconomic problems they face. The flaw in this study is that the research fails to provide qualitative data to supplement the questionnaire data used in the study.

The spatial manifestations, formations, and implications of slums on city life in Nigeria were investigated by Ribadu (2019). This investigation used secondary sources of data, including but not limited to World Bank policy papers, media coverage, United Nations Habitat Policy Reports, and pertinent academic literature on the subject. The growth and prevalence of slums in Nigeria have been attributed to a number of factors, including the country's large rural-urban migrations and natural rise, the lack of available urban housing, the inaccessibility of land, and above all pervasive poverty.

DISCUSSION OF FINDINGS

Objective one: To identify the most common types of social vices in the Ngnevu urban slum. This section explored the social vices that are prevalent in the Ngenevu urban slums. Social vices are any actions or behaviors that are considered harmful or immoral by society. These include things such as crime, violence, corruption, substance abuse, sexual misconduct, and more. However, the participants were asked to identify the most prevalent social vices in Ngenevu urban slums. Findings indicated that there are so many social vices in the study area. However, many of the participants explained that drug abuse, criminality, and thuggery are the common social vices experienced in the slums. Though drug abuse, criminality, and thuggery were considered the most common social vices, some of the participants had divergent views on the most common social vices in the slum area.

The following statements represent what the participants considered the types of social vices that exist in the study area.

"This slum has many types of social vices that involve cultism, prostitution, thuggery, rape, fighting, teenage pregnancy, gambling, insecurity, sexual abuse, drug abuse, etc. But the most common ones are criminality, cultism, and drug abuse. (FGD, female, 35 years old).

However, some other respondents expressed contradictory opinions about the prevalence of violence in the study area. For example, one respondent affirmed thus,

"My sister, challenges of social vices are much here" we have cultism, thuggery, criminality, drug abuse fighting, teenage pregnancy, gambling, (IDI / Female, 28 years.)

Additionally, participants were asked their opinions on the environmental issues and potential solutions.

A participants responded thus,
"Yes it affect our living condition. Most of us are living with hypertension some are restless, unclean environment. We have unclean environment, poor waste management system and the other factors that that contributing to the uncleanliness of the area. We need help to better our living condition. This finding supports the findings of Wajim, Garba, Shimfe, and Grace (2019), who highlighted that environmental problems, poverty, and unemployment, as well as crime and insecurity, are some of the social vices associated with urbanization in Nigeria. One can observed that all these vices may be attribute to poverty. When people are deprived of necessities such shelter, education, and food, they may turn to crime as a way to survive.

Objective two: To assess the effects of social vices on physical, mental, and emotional health among slum dwellers.

Further investigation was also sought to assess the effects of social vices on physical, mental, and emotional health among slum dwellers. Given the urbanization-related population increase, it was discovered that these vices have direct and indirect effects on the environmental health and quality of life of the residents. The effects comprise economic (decreased property values and reduced economic activity), physical destruction of property, leading to unsafe and unsanitary living conditions, and psychological effects, such as fear and anxiety. While indirect effects are those that occur as a result of the direct effects, For example, the physical destruction of property can lead to decreased access to healthcare and sanitation services. This, in turn, may lead to an increase in disease and illness, which is an indirect effect of cultism on environmental health and quality of life. The indirect effects are just as important as the direct effects, as both have a compounding effect on the overall well-being of residents.

The extract below states, thus:
"The effect is much greater, for example, the activities of the cultism; they bring fear to the community. When they clash, people entertain fear. It has serious emotional, psychological, and economic effects on the community. (FGD / Female, 32 years.)

Another participant also asserted this:
"Many times people fall victim to circumstances at in hands of law enforcement agents. Most innocent citizens are incarcerated for something they are ignorant of due to immoral behaviors in the slum. The incarceration of innocent citizens, the creation of security tension in metropolises, insecurity, sleepiness, which most times lead to illness, disruption of social, electoral, and economic activities, noise pollution, criminality, and destruction of life and property are also major effects of social vices in the community. (FGD / Female, 58 years.)

From the qualitative data gathered, these results are consistent with the assertion made by the World Health Organization (WHO), which promotes people's physical, mental, emotional, and social well-being, that stress and depression significantly increase the risk of a healthy lifestyle in urban areas.

Objective Three: Strategies adopted for addressing the social vices in the slum areas.

The opinions of the participants about the strategies used to address the social vices in the study are discussed in this section. The results showed that the respondents reported a wide range of strategies, such as having security agents (local vigilantes regularly monitor the community), avoiding staying up late, being vigilant about security in the community, fervently praying for help, approaching the government for assistance, creating job opportunities, improving the socioeconomic standing of the urban poor, locking up offenders, establishing community-based guards, placing security posts in the slum, Punishing the environmental offenders, working together with the government and non-governmental organizations to implement policies aimed at addressing urban slums, starting slum upgrading, discouraging indiscriminate dumping of refuse, The purpose of these steps is to guarantee security in slum areas. These opinions were buttressed further by a statement from the focus group discussion.

The explanation below is the participant's submission:
”*For this community to be free from problems, proper monitoring is required. We need the police to help us. Though we have local vigilantes, they have limited power. They can make arrests but cannot prosecute. Police sometimes constitute problems because when you report issues to them, it takes time for them to respond. The police post can only be located at Old Park, which is a little bit far from us. Our community has no police post, which is why we are finding it difficult when it comes to security matters. In fact, there is a need for regular monitoring of the community by the security agents so as to ensure a secure environment.* (KII, male, 55 years).

These results support Buhaug and Urdal's (2013) claim that the slums serve as breeding grounds for social and political unrest in urban areas.

CONCLUSION

This study is a cross-sectional descriptive study of the effects of social vices on environmental health and quality of life among Ngenevu urban slum dwellers in Enugu State. The study reveals that the most common social vices experienced by the slum dwellers in the study area are drug abuse, criminality, and thuggery. The study also finds that the effects of social vices on environmental health and quality of life among Ngenevu urban slum dwellers have a compounding effect on the overall well-being of residents. Thus, the study offered several recommendations.

RECOMMENDATIONS

The government needs to pay greater attention to the security networks in the slum areas in order to apprehend and prosecute individuals who are creating a hazardous environment. The government should establish a police department in the slum area in order to lessen the social vices that usually occur there, rather than treating them lightly and leaving them to wreak havoc in the community and the metropolis. Environmental offenders should pay fines so as to serve as a deterrent to others. There should be public awareness about the importance of proper waste disposal. The government should pay greater attention to the difficulties faced by slum residents in order to bring sanity to the slum areas.

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ENVIRONMENTAL POLLUTION AND SUSTAINABLE SCHOOL ADMINISTRATION: THE ROLES OF OPEN, DISTANCE AND E-LEARNING (ODEL) APPROACH

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ABSTRACT

The impacts of environmental pollution (EP) on schools are not only on the well-being of the students and teachers alone but can spread to different aspects of education, mental health and general community health. The impacts of EP on the students and teachers can affect the physical, mental and emotional wellbeing. This study therefore assesses the impacts of environmental pollution on the sustainable administration of schools and the roles ODeL can play in the adaptation and mitigation process. Qualitative multiple case studies and a review of relevant literature in the interpretive research paradigm were adopted in this research. Secondary data from prints and online media were sourced and arranged into themes for content analysis by looking at issues historically and holistically. It was suggested that strict regulatory measures on environmental protection should be legislated and implemented and that the digital transformation in educational administration and delivery through the ODeL approach should be supported and promoted for Global sustainability.

Key words: *Environment, Open Distant and e-Learning, Pollution, School*

INTRODUCTION

The quest for development through man's activities such as mining, industrialization, exploration and urbanization in the Global North and Global South has resulted in the burden of environmental pollution. According to the report from the Intergovernmental Panel on Climate Change (2007), the impacts of climate change such as drought, flooding, ocean acidification and other global warming drivers such as pollution and deforestation on the ecosystem are enormous.

The school system is a critical social infrastructure in the society for the development of the affective, cognitive and psychomotor competencies of the students are. The school is like a second home for the students. They spend most of their time indoors while at school (Grimsrud, Bridges & Schulte, 2006). The condition of the classroom learning environment is essential because Students spend about 12% of their time in the classroom. The classroom is known to be more congested than the Workplaces due to the density of the students in the classroom (Katafygiotou & Serghides, 2014). The school saddled with the responsibility of providing an optimal environment for the teaching and learning process.

According to Galbraith (2009), the step taken by some institutions is to promote sustainability through capital improvements such as improved school buildings (green building) and adjustments in school administration and operations (sustainability management). Another step, as reported in this study is to encourage schools to embrace ODeL. This study reviewed the impacts of environmental pollution on sustainable school administration and the environmental friendly roles ODeL can play.

Purpose of the Study

The purpose of this review is specifically to establish the relationship between Environmental Pollution and Sustainable School Administration, the mitigating and adapting roles the Open, Distance and e-learning (ODeL) approach can play, and to make suggestions on how to achieve sustainable administration of schools in the context of environmental pollution.

Concept of Environmental Pollution

Environmental Pollution refers to any addition of unwanted, toxic or harmfull material to the environment due to natural and human activities that can lead to ecological imbalance, undesirable changes in the environment and life threatening impacts on plants, animals and humans. The word environment was derived from the French word 'enviromer'. This means to encircle or to surround. An environment is every natural or man-made thing that surrounds or affects humans, animals or plants. There are two types of Environmental pollution (a). Natural Pollution: pollution of the environment by naturally occurring phenomena, such as cyclones, volcanic eruptions, floods, earthquakes, drought etc. (b). Man-made Pollution: pollution of the environment caused by the aftermath of Human activities such as mining, urbanization, afforestation, industrialization and agricultural activities.

METHODOLOGY

Qualitative multiple case studies and a review of relevant literature in the interpretive research paradigm were adopted in the research. Secondary data from prints and online media were sourced and arranged into themes for content analysis by looking at issues historically and holistically on Environmental Pollution and the mitigating and adaptive roles of the Open, Distance and e-Learning (ODeL) approach in environmental health.

Theoretical Support

This study is supported by the Theory of Sustainability. Thorstein Veblen (1917) and Pigou (1929) were the ones behind what we call sustainable development today. Generally, sustainability is a form of intergenerational practice that encourages economic and environmental actions to be taken in the present for the benefit of the future for the attainment of the same and better outcomes in terms of welfare, well-being and wealth.

The term "Sustainable Development Administration" is described as an aspect of public policy that deals with the application of the sustainable development paradigm to public administration structures, processes, and institutions like the school system.

The school administrator in conjunction with all education stakeholders must protect the well-being of the students and teachers presently and make decisions that will control, prevent or eradicate environmental pollution within the school system in the future. One such sustainable innovation is the open, distance and e-learning (ODeL) approach.

Forms of Environmental Pollution and their Impacts on School Administration

i). Noise Pollution

The sustained occurrence of loud or disturbing noise in the environment is referred to as noise pollution. The harmful effects of noise pollution in the school environment can cause auditory disorder (loss of hearing) due to regular exposure to loud and irritating sounds and inability to concentrate on the teaching-learning activities in the classroom due to the unhealthy distractions.

ii). Radioactive Pollution

Radioactive pollution is simply defined as the contamination of the environment with radioactive materials that are very harmful to the lives of humans, animals and plants due to the release of ionizing radiation into the environment. In the school science laboratory, radioactive materials can be used to perform some experiments. It is the function of the school administrators and the science teachers to make sure that the students and people in the school environment are protected from such radioactive substances in the laboratory or classrooms through proper storage and labelling (EPA, 2022).

iii). Air Pollution

In simple terms, the release of harmful substances into the atmosphere such that the natural composition of the atmosphere is negatively affected is what is referred to as air pollution. Causes of air pollution include; smoke from bush burning, incinerators, burning of refuse around the school, and smoke from generating plants used by residential buildings within the neighborhood where the school is located. Air pollution can have a devastating effect on human health ranging from primary damage to secondary damage such as; respiratory tract infection, skin irritation, eye and throat infection and suffocation among others (Gana & Toba, 2015).

iv). Land/Soil Pollution

The effect of land pollution can be detrimental to human health. The dump sites can provide a breeding ground for some disease vectors such as rats, flies, and mosquitoes;

these can lead to outbreaks of epidemics. For example, an outbreak of Lassa fever and some form of waterborne diseases. Glass and metal objects can lead to serious body injuries when stepped upon. Gullies caused by erosion can lead to accidental falls; excessive erosion over time may negatively affect the school buildings which can pose a risk factor to students. Erosion can also lead to the collapse of roads, culverts and drainage systems all of which can lead to students sustaining various degrees of injuries and learning loss (Abdul, 2020).

v). Thermal Pollution

When heat is rapidly discharged into a water source, it generates a high temperature which directly and indirectly affects the environment.

According to Jane (2021), warmer water may produce a ripple effect in the ecosystem because of the effects on aquatic farming which is a source of seafood for the inhabitants of the environment. Administration of schools may be hampered by thermal pollution because it increases the vulnerability of the students to some diseases such as meningitis and skin rashes which may result in the contamination of the entire school environment due to the infectious nature. Thermal environment pollution can cause an imbalance in the behaviour of students in the classroom to become more aggressive, take off clotting or lose concentration due to the inconveniences caused by the dehydration.

vi). Visual Pollution

Visual pollution is anything that impairs a clear view of the natural environment to appreciate the aesthetic value or looks. The effects of regular exposure to visual pollution include loss of identity, eye fatigue, distraction and a decrease in opinion diversity.

Sources of common visual pollution include debris, Billboards, electric wires, cabbages, antennas, obstructing buildings, automobiles and overcrowding in an area. Visual pollution in the school environment makes students feel uncomfortable and insecure.

vii). Water Pollution

Water pollution has been reported in several studies as the major cause of diarrhoea, enteric fever, morbidity and mortality (Nauges & Strand 2013; Wolf *et al.* 2014) while clean water supplies and sanitation in the school environment improve school attendance (Dreibelbis *et al.* 2013). A study by Ahmad & join smit (2019) on the Effects of water and health on primary school enrolment and absenteeism in Indonesia found out that the accessibility of clean water in the school environment can improve academic outcome, negatively significant to school absenteeism and positively significant to school enrolment. The result indicated the importance of portable water to students' well-being and schooling activities

The Justification of ODeL as an Environment-Friendly Approach
Open, Distance And E-Learning (ODeL) is an excellent educational innovation that offers collaboration, convenience, quality, cost reduction, no barriers and a personalized experience. The ODeL approach reduces the negative environmental impacts (pollution) that emanate from human activities such as manufacturing, mining, agriculture, urbanization and transportation. There is a reduction in the materials (nonbiodegradables) needed to set up an ODeL institution such as desks, textbooks, buildings, electricity metals, plastic, wood and other construction materials when compared with conventional institutions. This conserves natural resources and reduces waste (land pollution).

Additionally, ODeL economically saves the time and finances for the students, the facilitators and the learning institution.

Studies have already established that the ODeL methodology reduces carbon emissions (Li et al., 2020; Versteijlen et al., 2017) and can reduce air pollution due to the significant reduction in the carbon footprint between the conventional and the ODeL institutions (Filimonau et al. (2020).

The daily movement of students to school increases the levels of pollution and emissions. The ODeL approach allows the students to access education from the comfort of their various locations. This, as ascertained by Campbell & Campbell (2011) that the ODeL approach can reduce carbon dioxide emissions (air pollution) drastically each semester

According to Roy et al. (2008), ODeL programmes involve 85% lower CO2 emissions and 87% less energy than conventional full-time programmes. Roy et al. (2008) further documented that due to the level of energy consumption during computing and printing, there is a 20% and 12% reduction in the E-learning approach when compared with print-based distance learning. In addition, Harlow (2016) made it clearer that the rate of emission in Online studies was, on average, one-third of on-campus studies.

Caird et al. (2015) also observed that there is an 88% reduction in the rate of energy consumption and a 83% in carbon reduction in ODeL-based models when compared with campus-based educational models. Gamba et al. (2021) further noted that in a hybrid (Blended) educational approach, a 15% reduction in gaseous emission (air pollution) can be achieved with significant changes

The rate of water waste in ODeL is less than that experienced in a commercial building such as a school because most of the volume of water used in the educational facilities are used in the cafeteria, restrooms, and heating/cooling in the offices or hostels (Dziegielewski, et al., 2000). Water wastage can pollute the environment (land pollution) and serve as a breeding ground for mosquitoes and other disease vectors. In addition, wasted food is also reduced in ODeL when compared to traditional educational institutions. Wasted food is also known to produce greenhouse gases. Moreover, when wasted foods are discharged into the landfill (land pollution), it produces methane which is a greenhouse gas (air pollution) that has a more powerful effect than carbon dioxide (Kumar & Nadda, 2023)

CONCLUSION

Human survival depends on the environment. Therefore, we must embrace a 'green vision' as part of our sustainable administration of schools because as we are harming nature through our ambitious activities, nature will harm us more. Although ODeL cannot replace face-to-face education completely, introducing it as a supplement to conventional learning can reduce the impacts of pollution on our environment drastically. Without any doubt, ODeL is yet to achieve full acceptance. The fact that ODeL is friendly to the environment can only help.

RECOMMENDATIONS

Trees should be planted in our surrounding, especially in the school environment. Strict regulatory measures on Eco-friendly practices should be legislated and implemented. The digital transformation in educational administration and delivery through the ODeL approach should be supported and promoted for Global Sustainability

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HEALTH PLANNING: IMPLICATIONS OF FAMILY POULTRY ON AIR QUALITY WITHIN RESIDENTIAL NEIGHBOURHOODS IN IBADAN REGION, NIGERIA

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ABSTRACT

Family poultry farming is undergoing a major intensification in many cities in Nigeria. This increase is anticipated to pose or create new environmental and public health threats having pandemic potential in cities. This study examined air pollution from family poultry farming and how urban and regional planners can evolve environmental safety guidelines for family poultry activities within residential neighbourhoods. The study was anchored on the healthy city concept. Adopting a mixed method design, primary and secondary data were sourced from a total of 730 family poultry owners and 20 stakeholders purposively selected using a semi-structured questionnaire from eight local government areas (LGAs) in Ibadan Region with high preponderance of poultry activities. Data obtained were analyzed using Chi-Square and Multinomial Logistics Regression Model while qualitative data were content-analysed. Findings revealed that family poultry family in the Ibadan Region was characterised by non-existing guidelines, poor waste management practices which were detrimental to human health. There were no significant differences in the concentrations of odorants across the LGAs. Air Quality Index (AQI) ranged from 87-194 ug/m^3 against the minimum standard of 0-50 ug/m^3 across LGAs revealing that air is polluted and unhealthy, mostly for sensitive groups. About 96% experienced allergic (respiratory and skin) reactions. The study affirms air pollution through inappropriate waste and sanitation management of family poultry. To reduce further pollution and promote healthy city, study suggests that the government should carry out massive public awareness campaigns and review existing space standards and environmental regulations. A "Minimum Feasible Standards" was proposed for the planning authorities.

Key words: *Environment, Family Poultry, Public Health, Risk, Residential areas*

INTRODUCTION

The global human population is growing rapidly and consumption patterns are shifting towards a significant and increasing demand for animal products (Food and Agriculture Organization (FAO), 2014). Poultry and its products now constitute about 90 per cent of animal protein consumed by the populace.

Poultry is reared in different ways ranging from small, village-level scavenging flocks from which only few poultry enter the formal market system, to integrated intensive operation in which large companies control all aspects of the production and marketing chain upstream and downstream from production units (Aderounmu et al., 2020). In between this lies a range of systems from individual farms practicing to industrial type of production termed family poultry. The family poultry production is system of production that encompasses the full variety of large, medium and small-scale poultry production found in rural, urban and peri-urban areas of developing countries.

Family poultry is the prime type of poultry kept in the world (Ranwedzi, 2002). Before now, more than 80% of family poultry are kept in rural areas (Sonaiya, 2007). This type of poultry has found its way into per-urban and urban areas as a home-based enterprise constituting an important part of food security for households in Nigeria. This is owing to Nigeria's livestock sector not meeting up with the demand for animal source protein, urban poverty, food insecurity and unemployment (FAO, 2019). Chen and Sinha (2016) described these as informal activities found within informal settlements. That is, having work-sites (as the case of family poultry farms) located in residential buildings and homes (De Soto, 1989).

Based on reviewed literature (Adene and Oguntade, 2015; Awogboro et al., 2019), there has been massive increase in the production of family poultry both at small and large scale levels owing to high levels of food insecurity, unemployment and urban poverty in Nigeria. Amongst the vast research available on poultry production, very little empirical research has been carried out on the nature and development of family poultry as a home-based enterprise in Nigeria. To this end, this study seeks to examine family poultry

The research objectives are to identify the defining characteristics of family poultry in Nigeria using Ibadan as a case study, examine its potentials and constraints and access institutional framework available for its administration and management in Nigeria.

MATERIALS AND METHODS

This paper is based in part on a thorough review of the literature on family poultry production in Nigeria and an empirical study on Family Poultry in Ibadan Region, Nigeria. Several global databases were searched and articles identified in these sources were also used to identify additional relevant sources.

Study Area

The study area for the study is the whole of Nigeria using Ibadan Region as a Case study. The case study was carried out in Ibadan situated in south-western region of Nigeria. The city covers a total of 3,123.30km^2. The Ibadan metropolitan area is made up of eleven (11) local government areas (LGAs). Five (5) of these constitute the urban local government, namely: Ibadan North, Ibadan North East, Ibadan North West, Ibadan South East and Ibadan South West while the remaining six (6) LGAs, namely Akinyele, Egbeda, Ido, Lagelu, Oluyole and Ona-Ara, are considered as rural (Wahab and Abiodun, 2015). The study was carried out in eight local government areas with high preponderance of poultry farming among the 11 local government areas in Ibadan Region, Nigeria.

Data and Data Analysis

Data for this study were elicited from both primary and secondary sources. The secondary data employed include the estimated number of poultry farmers within Ibadan, obtained from the Oyo State Agribusiness Development Agency (OYSADA) and the Livestock Department of the Ministry of Agriculture, publications of government and quasi-government agencies such as the Oyo State Gazatte on Environmental (Sanitation and Wastes Control) Regulations, 2013 and published journal articles. Primary data were sourced mainly through direct field survey and observations. The main instrument used for the collection of the primary data was a semi-structured questionnaire administered to family poultry owners in the study area. Adopting a multistage sampling technique, a total of 730 farmers, which constituted 0.2% of the total poultry farmers in (8) urban and peri-urban local governments in Ibadan with high prevalence of poultry including Ibadan North West, Ibadan South West, Oluyole, Ona-ara, Ido, Akinyele, Egbeda and Lagelu LGAs, were randomly selected for questionnaire administration. To ascertain the environmental and health impact of family poultry farming on air quality, the study examined the odour concentration as a measuring parameter for odour pollution. Odorants associated with poultry production that were measured include carbon monoxide (CO), nitric oxide (NO), nitrogen oxide (NO_2), sulfur dioxide (SO_2), ozone (O_3), ammonia (NH_3), and particulate matter ($PM_{2.5}$ and PM_{10}). To achieve this, the ambient air quality of poultry farms was measured and recorded using the Atmotube and Air Meter device via the Air Quality Score Android app alongside the questionnaire administration. The absolute scores and values of the odorant were taken for each of the residential buildings, and they were recorded. Data obtained were analyzed using Statistical Package for Social Science (SPSS). The results were presented in tables and percentages.

RESULTS AND DISCUSSION

This section examines the socio-economic characteristics of poultry owners in Ibadan. The socio-economic variables considered relevant for this study include: sex, age, marital status, religion, highest level of education, other occupation, and monthly income.

SOCIO-ECONOMIC CHARACTERISTICS OF FAMILY POULTRY OWNERS

The sex, age, marital status and religion of the family poultry owners were examined. Results showed that family poultry owners were predominantly male (61.9%). Respondent’s age was 43.0±9.9 years and males distributed among two major religious beliefs in Nigeria. About 90% had formal education, with 7.0±0.5 years farming experience and 46.6% earned less than ₦30,001.00 monthly. This is in consonance with the findings of Aderounmu and Oyewo (2019) and Ayo-Bello et al. (2021) that majority of family poultry owners have high literacy level. This indicates that, the percentage of literate family poultry owners is high showing less difficulty as regards disseminating information about new practices on how to improve poultry practice and ensure environmental safety.

Results established that a large percentage (88.3%) of respondents combined poultry with other occupation to sustain their living. This implies that, poultry farming activity is majorly used as a livelihood supplement and not practiced within residential areas solely as the primary livelihood asset

FAMILY POULTRY IN IBADAN AND ITS HEALTH AND ENVIRONMENTAL IMPLICATIONS

Four family poultry production were discovered during the survey. These are egg production, meat production, hatchery production and combination of egg and meat production. The systems employed among family poultry owners were the free range/ extensive scavenging system of production and semi-scavenging method of production. Majority of the owners across Ibadan raised chickens with an average of 93.2 more than other birds among poultry farmers in the 8 LGAs. Poultry owners who raised chickens raised exotic breeds of chickens such as local breeds, noilers, broilers, and kruoilers (49.3%). Other birds raised include: turkey (22.4%), local/ traditional chickens-cockerels, pullets, hen (15.5%), ducks (local ducks (10% and muscovy ducks (3.8%), guinea fowl (3.8%) and parrots (2.0%).

Half of the owners had a flock size of 1-500 birds while 24% had flock size of between 500 and 1500 birds. 10.1% of the farmers had flock size between 1501 and 2500. Only 15.1% of the respondents had above 2500 birds. Flock sizes varied across LGAs (H-test (3) = 661.5) and they comprise chickens, turkeys and ducks. Poultry system adopted was a function of housing ownership tenure (χ^2 (15) = 34.72), income (χ^2 (3) = 30.49) and education (χ^2 (9) = 43.26). There was a low adherence to residential space standards (3.7%) in all the LGAs.

The result of the average odorant concentrations for all odourants measured is presented in Table 5. Analysis revealed that, although CO levels were high, they were not significant contributors to odour experienced within the residential building. These findings show that NO and NO_2 concentrations were high, meaning that the air is polluted with particle pollution that could cause a range of upper respiratory infections, such as coughing, wheezing, and so on. Likewise NH_3 and SO_2 were in high concentration which could be a potential cause of various respiratory problems outlined by farmers and residents in the residential buildings where poultry is operated. Examples of the symptoms that may result from the concentrations of these odorants as measured by Panjagal and Ramaiah (2021) include: nausea, coughing, sneezing, headache, loss of sleep, irritation (eyes, throat, and nose), respiratory problems, fatigue and dizziness, etc. In summary, the level of odour concentration from the examined gases in the study showed that the odour generated from family poultry shelters within residential buildings was harmful to the well-being of the building occupants and to all who live within and around the environment.

The variation in the average observed odour unit and the expected odour unit is depicted in Table 1. In addition, the AQI scores obtained from the Atmotube Pro. using the air mean score established that the level of odour concentration was high in the eight LGAs. Air is polluted because all the AQI's from the 8 LGAs were above average, ranging from 87-194 ug/m ^{3} above the minimum standard of 0-50 ug/m ^{3}. They were between 4 and 5, as shown in Table 2.

Table 1: Characteristics of Odour Concentration in Residential Buildings with Poultry Farms

Odorants	Average odorants (Ug/m^3)	AverageLimits (Ug/m^3)	Standard Deviation	Remark
CO- Carbon monoxide	1114.4	2000	389.68898	Below limit
NO- Nitrogen Oxide	294.92	200	6.7873	Above limit (High)
NO_2 –Nitrogen Dioxide	459.19	200	23.7783	Above limit (Very High)
NH_3- Ammonia	555.34	400	18.6764	Above limit (High)
SO_{2-} Suphur Dioxide	41.847	20	2.13762	Above limit (Very High)
O_3- Ozone	42.8642	100	1.702119	Below limit
PM_{10}- Particulate Matter	68.9750	50	3.363649	Above limit (High)
$PM_{2.5}$- Particulate Matter	52.4013	25	2.014669	Above limit (Very High)

Source: Field Survey (2021)

Table 2: Atmotube Pro. Measurement Interpretation

AQI Index	Index Rating	Interpretation	Odour concentration
81 and above	5	Air is severely polluted	Extremely strong
61-80	4	Air is very polluted	Strong
41-60	3	Air is polluted	Faint but perceivable
21-40	2	Air is acceptable	Barely perceivable
0-20	1	Air is Satisfactory	No odour

Source: Atmotube Pro. (2021)

Perceived Health Effects of Family Poultry within Residential areas

The study established that there was a low level of awareness and knowledge of the hazards associated with poultry farming. Majority of households (72.9%) had little knowledge of the health risks associated with urban poultry farming. They were not aware of the presence of the hazards, nor were they aware of the factors predisposing them to the hazards.

The study opined that 37.1% of poultry owners were found to suffer from allergic reactions to poultry, resulting in flu-like symptoms like cough and catarrh. However, 18.2% of the respondents experienced some incidents of diarrhea or dysentery resulting from the use of contaminated water in their households, while 7.8% had cholera. Skin reactions (eczema and rashes) were another health hazard experienced by 13.2% of the respondents when they started poultry farming, while 13% had witnessed restiveness or sleep apnea owing to the noise from poultry birds, usually in the afternoon. A small percentage of 6.6% of the farmers had experienced asthmatic reactions and shortness of breath, while 4.1% could not say specifically if they had experienced any health challenges as a result of raising poultry. Thus, it can be inferred that, at least, 96% of family poultry owners had experienced one or more health challenges as a result of operating poultry in residential areas.

The study provided a percentage-based ranking of the most prevalent health issues that poultry owners in the research area reported. The succession of allergic reactions and respiratory infections causing catarrh and cough, shortness of breath, and asthma were ranked the highest, while contaminations resulting in dysentery, diarrhea, and cholera were the second highest. This shows that the air quality around residential areas where poultry farming is carried out poses a great health risk to all that lives within and around the building. These common health issues among poultry producers in the research area are caused by inhaling endotoxins and other tiny organisms prevalent in the air. The results of this study were corroborated by the findings of Aderounmu et al. (2020), who found that poultry farm workers were predisposed to great health hazards. Similarly, a study carried out by Akanni and Benson (2014) in Ogun State regarding the environmental implications of poultry waste on human health gave similar conclusions. The study asserted that many poultry farms established and located within 1km of residential buildings were sources of health and environmental concerns. This is because residents who live within a mile of the farms sometimes complain of restlessness, malaria, sneezing, and/or nausea. Gbotosho and Burt (2013) also noted cases of cholera breakout, reptile attacks (mostly snake attacks), and attacks by wild animals.

Coping Strategies to Minimize Identified Health and Environmental Nuisances

Several techniques and management practices by which family poultry owners control the local disturbances and environmental effects mentioned were also identified during the study. Only about 5% of respondents within the residential buildings do anything to complain or confront poultry owners causing these nuisances, despite acknowledging the identified local disturbances.

However, 18.4% of poultry owners cope with the identified nuisances by permanently shutting the doors to their building entrances, rooms, and windows. On the other hand, 26.3% of households confronted poultry farming households, which sometimes resulted in conflicts within the residential building and the neighborhood.

About 8.9% of the respondents made verbal complaints to poultry owners within the residential buildings, while 7.5% of households had to make formal reports to landlord associations and environmental health officials reporting local disturbances to them. To resolve the smell and odour emanating from poultry shelters, strategies employed by farmers include the use of chemical disinfectants (12.7%), buying odour free feed for birds and the use of organic herbs mixed into bird feed (7%) (for example, the addition of garlic and ginger, lavacide, and adlibtum to bird feeds), sun-dried woven baskets (6.3%), and the use of a suspended cage on a water pond (2.5%). It was opined that the coping strategies employed were informed by the level of education and occupation of adjoining residential building owners.

CONCLUSION

Poultry production of any size has been widely reported as a major environmental hazard. Poultry facilities are one example of a building source of odour that creates local nuisance (Ranveer et al. 2015). There were no significant differences in the concentrations of odorants across the LGAs. Air Quality Index (AQI) ranged from 87-194 ug/m^3 against the minimum standard of 0-50 ug/m^3 across LGAs revealing that air is polluted and unhealthy, mostly for sensitive groups. About 96% experienced allergic (respiratory and skin) reactions. Problems with odour were typically limited to residential buildings and their surroundings. Odours were a significant local issue that were commonly cited by farm neighbors as the most unsettling environmental impact of poultry, even if extended exposure may raise public health concerns.

RECOMMENDATIONS

The first recommendation is the proper definition of family poultry and poultry enterprises within the Nigerian context, which had not been sufficiently established before this study was conducted. This will make family poultry recognized as a small-scale poultry production system by the Oyo State Agribusiness Development Agency and the Livestock Department in the Ministry of Agriculture. This will enable sustainable poultry farming and open up farmers to extension services, relevant information, and the best practices of poultry farming in urban centers. Secondly, the government should carry out massive public awareness campaigns, while the Bureau of Physical Planning and Urban Development should review existing space standards to include space standards for agricultural activities. In addition to this, inclusion of poultry guidelines should be provided for residential development proposals sought from the Planning Offices. The environmental regulations and guidelines regarding waste and sanitation should also be reviewed to contain guidelines for managing poultry waste in Oyo State by the Ministry of Environment and Natural Resources.

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IMPACT OF AIR POLLUTION ON ECONOMIC GROWTH IN NIGERIA

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ABSTRACT

Assessing the impact of air pollution on economic growth involves analyzing various factors including sources and types of pollution, the extent of pollution, and its effects on health, productivity and environmental quality. Pollution is a disturbance not only to the environment but also to the economy most importantly to the agriculture and petroleum sectors of the economy. This research investigates the relationship between air pollution and economic growth in Nigeria, focusing on the period 1990-2022 using World Development Indicator data. Air pollution was captured by nitrous oxide emission, carbon dioxide emission, methane emissions and other greenhouses gases while gross domestic product (GDP) was used as a proxy for economic growth. Augmented Dickey-Fuller (ADF) unit root tests together with Autoregressive Distributed Lag (ARDL) models were employed for the analysis. The ADF unit root test revealed that all variables were stationary at first difference except Gross Domestic Product (GDP) which was stationary at its level form. The results of ARDL reveal that methane (CH4) emissions have a significant negative impact on economic growth. This suggests that reducing methane emissions could contribute to economic development. Carbon-dioxide ($C0_2$) and other greenhouse gases (GHG) have negative and insignificant effects on the GDP while nitrous oxide emission has a positive insignificant effect on the GDP. Based on the findings, the study recommends proper implementation and more policies to reduce methane emissions. It is also suggested that more emphasis should be laid on the consumption of renewable energy to reduce methane and other gas emissions. By addressing air pollution, Nigeria can not only improve environmental quality but also promote sustainable economic development.

Key words: *air pollution, impact, economic growth, emissions, Nigeria*

INTRODUCTION

The environment plays a vital role in sustaining the livelihood of the growing population in African and other emerging economies, which mainly depend on crop production, animal husbandry, fishing, hunting, foraging, forestry, handicraft, and small-scale mining. Sustainable Development Goals 3, 6, and 11 emphasize the need for economic livelihood while maintaining a quality environment (Oyebanji *et.al* 2017). Greenhouse gas (GHG) emissions are one of the significant causes of climate change. According to the Carbon Disclosure Project (CDP, 2020), Africa contributes the smallest portion of global GHG emissions, at only 3.8%, compared to advanced industrial economies such as China, the United States, and the European Union. Between 1884 and 2020, Africa's aggregate carbon dioxide CO2 emission was about 48 billion metric tons, and world emissions reached almost 1.7 trillion metric tons from the beginning of the industrial revolution in 1750 until 2020 (IPCC, 2022). The connections of economic activities with environmental pollution determine the actualization of green growth and sustainable development in many economies (Gershon and Mbajekwe, 2020). The efficient use of energy systems has been argued in the literature to be a result of economic development in most economies of the world (Romanus *et.al* 2020; Alege, *et.al* 2016). On the other hand, carbon and nitrous oxide emissions from sources such as fossil fuel combustion, carbon dioxide emissions, fertilized soil, and animal waste, among others, have resulted in externalities with a negative impact around the world. This is because energy use, especially fossil fuel use, as well as activities such as production and construction, have had unfavourable effects on the environment, resulting in deterioration of the environment, poor health outcomes, and a shorter life expectancy (Matthew *et.al* 2020; Matthew *et.al* 2018).

Economic development is one of the macroeconomic priorities in Nigeria that cannot be compromised (Nchege *et.al* 2022). The country's energy demand is increasing across all sectors of the economy to achieve economic growth. Transportation alone accounted for 47.76 percent of CO_2 emissions in Nigeria between 2000 and 2014 (IEA, 2020). Nigeria is also a significant producer and consumer of fossil fuels, identified as the primary source of CO_2 emissions causing global warming (Alege *et.al* 2016). The government has implemented policies such as carbon pricing and proper animal waste management over the years to reduce the environmental effects of carbon dioxide and nitrous oxide emissions. However, the effectiveness of several past and current environmental policies in achieving desired results remains a key issue. This study aims to investigate the relationship between air pollution and Nigeria's economic growth as the country's population increases, and the energy situation worsens (Akinyemi *et.al* 2021 and Ugwoke *et.al* 2020). This study is crucial in designing policies that achieve economic development while ensuring environmental sustainability in a post-COVID-19 era with widening inequality (Adeleye *et.al* 2020).

RESEARCH METHODOLOGY

Study Area

The study focuses on Nigeria, a country situated on the West Coast of Africa. Nigeria covers approximately 923,768 square kilometers of land and shares borders with Chad and Atlantic Ocean to the South, Niger Republic to the North, Cameroun to the East, and Benin to the West. The country comprises of 36 States and the Federal Capital Territory, which are further divided into 774 Local Government Areas. The population in Nigeria is unevenly distributed, with about 63 percent residing in rural areas and the remaining population in urban areas (NBS 2019). As of February 2022, the estimated population of

Nigeria is 214,587,291 people, according to the latest projections from the United Nations data (UN Worldometer data 2022).

METHODS OF DATA ANALYSIS

Source of Data

The study employed secondary time series data of 33 years spanning from the years 1990 to 2022. The data was collected from the World Development Indicator (WDI). The variables are; gross domestic product (GDP), nitrous oxide NO_2, carbon dioxide, CO_2, methane CH4, and other greenhouse gases, GHGS. The choice of the variables as measure of air pollution is based on the fact that they form main components of greenhouse gases emission and GDP as a measure of economic growth (Nchege *et.al* 2022)

Model Specification

The Autoregressive Distributed Lag (ARDL) model is employed in this study to analyze the data and investigate the relationship between air pollution and Nigerian economic growth. The mathematical representation of this relationship is as follows:
GDP = f (NO_2, CO_2, CH_4, GHGS)
Where
GDP= Gross Domestic Product
CO2= Carbon dioxide emissions
NO2= Nitrous oxide
CH4= Methane
GHGS= Other Green House Gases
Specifying equations in ARDL model;

ΔLGDP=b0+j-0rb1ΔLCO2t-j+k-osb2ΔLNO2t-k+i-oub3ΔLCH4t-l+l-0vb4ΔLGHGSt-m +1 LGDPt-1+2 LCO2t-1+3 LNO2t-1+4 LCH4t-1+5 LGHGSt-1+e1 (1)

The different terms in equation (1) represent the short-run variables, while the lag terms in the latter half of the equation show the long-run process. e_2 is the error term. The long- and short-run parameters of the variables are bi (i = 1,2,3,4) and φi (i = 1,2,3,4,5). Using Akaike knowledge collection criteria, the optimum lag period would be calculated. The error correction representation of equation (2) is:
ΔLGDP=b0+j-0rb1ΔLCO2t-j+k-osb2ΔLNO2t-k+i-oub3ΔLCH4t-l+l-0vb4ΔLGHGSt-m+ b5ECM2t-1+e2 (2)

Where ECM2t-1 is the error correction term

RESULTS AND DISCUSSIONS

Augmented Dickey-Fuller Unit Root Test

The unit root is a property of a stochastic mechanism that can trigger problems in statistical inference when dealing with time series. If 1 is a root of the process's characteristics equation, the process has a unit root. A non-stationary phase, on the other hand, does not always have a pattern. In the presence of a shock, the unit root phase has a permanent effect on the mean (that is, it does not converge over time). An explosive process is described as one in which the process characteristics' root is more significant than one. A unit root can be tested in a variety of ways using ADF test method and the Philips Perron test protocol (Nchege *et.al* 2022; Kabiru *et.al* 2020, Aghanenu *et.al* 2018) .This study employed the Augmented Dickey-Fuller unit root test technique. The ADF unit root test is applied in estimating the following model:

$\Delta yt =\beta+t\ yt\text{-}1 +i=1qi\Delta yt\text{-}i +t$ (3)

Where

Δ = first difference operator
yt = the time series variable of interest at the current period, t
= drift parameter to be estimated
= coefficient on-time trend, t
= test parameter
q = To calculate the maximum lag time empirically, lag order selection criteria such as the
Swartz Bayesian information criterion (SBIC), Akaike information criterion (AIC), and Hannan Qin information (HQIC) criterion are used.

Whether or not to include or is an empirical question. Thus, there are three possibilities with the ADF test, a situation where: (i) the test model includes β but not δ (the series has drift but no trend); (ii) the test model includes both β and δ (the series has drifted and it is trended) and; (iii) the test model does not include β nor δ (the series has no drift nor trend). The null hypothesis of the ADF test is Ho: $\theta = 0$ (yt is non-stationary) against the alternate Ha: $\theta < 0$ (yt is stationary). The rejection of null hypothesis implies no unit root. Where Ho has not rejected the test will be conducted at first difference. This involves estimating (3).

$\Delta\Delta yt =\beta+t\ yt\text{-}1 +i=1qi\Delta\Delta yt\text{-}i +t$

Where all the variables remain as previously found, but this time the series is differenced twice as indicated by the second difference operator, $\Delta\Delta$ and the test parameter is the coefficient on the first-differenced one lag of y, $\Delta yt-1$.

The Augmented Dickey-Fuller (ADF) test was used to examine the stationarity of the variables under consideration. The results of the ADF test revealed that the GDP is not stationary in its level form, but the lag of GDP becomes stationary at its level form. In absolute terms, the respective test statistic at the level form exceeds the 5% critical value. Similarly, the level forms of carbon dioxide emissions, nitrous oxide emissions, methane, and other greenhouse gas variables are not stationary at their level forms. However, the lags of these variables become stationary at the first difference. The level form test statistics are less than the critical value at the 5% level in absolute terms but exceed the critical value at the 5% level at first difference. The null hypothesis of unit root presence was rejected for carbon dioxide emissions, nitrous oxide emissions, methane, and other greenhouse gases variables. In this case, these variables were first differenced and then tested in a model with a drift and lag length of one. At the first difference, the variables were stationary at 5%. In absolute terms, the Augmented Dickey-Fuller test statistics at the first difference are more significant than the 5% critical value (Nchege *et.al* 2022; Kabiru *et.al* 2020, Aghanenu *et.al* 2018). Using the Augmented Dickey-Fuller unit root measure, carbon dioxide emissions, nitrous oxide emissions, methane, and other greenhouse gas are integrated of order 1, and the lag of gross domestic product is integrated of order 1.

Table 1: Augmented Dickey-Fuller Unit Root test

Variables	Statistics	ADF-Test Critical values 1%	5%	Order of integration
LGDP	-4.6129***	-3.6537	-2.9571	Stationary in level I(0)
LCO2	-2.0594	-3.6616	-2.9604	Non stationary in level I(0)
	-5.5258***	-3.6616	-2.9604	Stationary at first difference I(1)
LNO2	-1.7495	-3.6616	-2.9604	Non stationary in level I(0)
	-5.5475***	-3.6616	-2.9604	Stationary at first difference I(1)
LCH4	-0.5170	-3.7020	-2.9801	Non stationary in level I(0)
	-2.2010***	-3.7021	-2.9801	Stationary at first difference I(1)
LGHG	-1.8196	-3.6537	-2.9571	Non stationary in level I(0)
	-6.3315***	-3.6616	-2.9604	Stationary at first difference I(1)

Author's computation 2023 WDI data 2023

Relationship between air pollution and Economic Growth in Nigeria

The study used Gross Domestic Product (GDP) as the dependent variable to represent economic growth and carbon dioxide, methane, nitrous oxide, and other greenhouse gas as independent variables. The ARDL model reveals that methane significantly and negatively affects economic growth, while carbon dioxide and other greenhouse gases have a negative relationship with economic growth, although not significant. Nitrous oxide, on the other hand, has a positive relationship with economic growth, although not significant. Therefore, reducing methane emissions is crucial for sustainable economic growth in Nigeria.

The findings of the study suggest that methane emissions have a significant negative impact on economic growth in Nigeria. The result is relevant to the findings of Mehmood *et.al* 2021; Yusuf *et.al* 2020, and Rehman *et.al* 2020 who also found out that methane emissions have negative impact on economic growth. This implies that reducing methane emissions in the environment could lead to an increase in economic growth. Additionally, the study shows that carbon dioxide and other greenhouse gases have a negative relationship with economic growth, although not at a significant level. Nitrous oxide, on the other hand, has a positive relationship with economic growth, although not significant at any level. Overall, it is clear that reducing emissions of methane, carbon dioxide, and other greenhouse gases is important for promoting economic growth in Nigeria (Nchege *et al*., 2022; Kabiru *et al*., 2020).

Table 2: Autoregressive Distributed Lag (ARDL) models

Variables	Coefficient	Std. error	t-statistics	Prob.
Carbon dioxide	-0.0000659	0.0001170	-0.56530	0.5781
Methane	-0.0003870	0.0000864	-4.480149	0.0002***
Nitrous oxide	0.00000792	0.0001990	0.0397230	0.9687
Other GHG	-0.00000439	0.0000490	-0.089687	0.9294
Constant	2.2861100	1.665450	1.5579260	0.0002***

R squared 0.9512

Adj. R squared 0.6581 Prob. > F = 0.0130

Sample: 1990 - 2022

Author’s computation 2023 *** significant at 1%, ** 5% * 10%

CONCLUSION

Based on the study's findings, it has been revealed that air pollution has a significant impact on economic growth in Nigeria. The study examined data from 1990 to 2022, covering a period of 33 years, and found that while Gross Domestic Product (GDP) was stationary, air pollution indicators such as carbon dioxide, methane, nitrous oxide and other greenhouse gases were not stationary at their level forms but became stationary at first difference order I(1). The study also found that methane emissions have a significant negative relationship with economic growth, indicating that an increase in methane emissions in the environment can endanger economic growth. Carbon dioxide and other greenhouse gases were found to have negative but less significant impacts on GDP, while nitrous oxide emissions demonstrated a positive relationship with economic growth, although not at significant levels. To promote sustainable economic development in Nigeria, it is recommended that proper actions should be taken to reduce methane emissions into the environment. Additionally, it is suggested that more emphasis should be placed on the consumption of renewable energy to reduce methane and other greenhouse gas emissions. By addressing air pollution, environmental quality can be improved, and sustainable economic development can be promoted in Nigeria.

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A SYSTEMATIC REVIEW ON THE EFFECTIVENESS OF PLASTIC WASTE MANAGEMENT POLICY IN AFRICA

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ABSTRACT

One of the main materials found in regularly created inorganic solid waste is plastic. Merely 9% of the estimated 6.3 billion tons of plastic garbage generated globally to date has been recycled. The remaining 79% has been disposed of in the environment, with another 12% being burned. It is projected that by 2060, the amount of plastic waste produced would triple, if not worsen. This study examined several journals and articles on policies for managing plastic waste. A systematic review understand why policies are not effective. Findings show that plastic policies should clarify how primary packaging and goods are managed, and they should address potential sources of exempted plastic waste in order to potentially increase the adoption of policy instruments in every given region. Policies like bans were found to be primarily driven by environmental, economic, and societal concerns. With worldwide treaty's absence, a lack of support from stakeholders, and failures in enforcing and monitoring numerous prohibitions will further reduce most policies success rate. Policies banning plastics (especially single use plastics) have been implemented in the majority of African nations, although they have not had much impact due to inconsistency and lack of enforcement. The study recommended that biodegradable substitute be used in place of less effective waste management as sustainable solution. For policies on plastic waste to be successful, variety of stakeholders must be involved both before and after the policies are made and utilize a combination of techniques which target multiple audiences within the system. A more comprehensive life cycle-based data and labeling system that reflects the genuine environmental implications for producers as well as consumers will require significant investments in research and development including evaluation, monitoring and reporting indicators.

***Key words**: Plastic waste management, Life cycle assessment, Policy ineffectiveness, Africa*

INTRODUCTION

The word "plastic" comes from the Latin word "plasticus," which itself comes from the Greek word "plastikos," which was used to describe material that had the potential to be molded or suited for molding at the beginning of the 17th century (Ncube et al., 2021). Because of their inexpensive cost of molding into various forms and features and their special material qualities (such as being lightweight and hydrophobic), plastics are widely used in the economy. Merely 9% of the estimated 6.3 billion tons of plastic waste generated globally to date has been recycled. The remaining 79% has been disposed of in the environment, with another 12% being burned. 80 percent of marine litter is made up of plastic waste, with an estimated 4.8–12.7 million metric tons of plastics dumped into the ocean year (Hira et al 2022) Upstream waste avoidance and downstream waste recovery strategies within the plastic industry must be implemented to combat plastic pollution lifecycle.

In comparison to the global average of 43 kg/person/year and the 100 kg/person/year in Western Europe and North America, the average plastic consumption rate in Africa is 16 kg/person/year. After Asia, Europe, and North America, Africa and Latin America create the fourth most plastic waste (Babayemi et al., 2019). However, Africa is the world's second-largest emitter of improperly managed plastic waste, after Asia, due to poor waste management systems and illegal waste imports (Lebreton and Andrady, 2019). By 2060, the amount of plastic waste generated is predicted to triple. To make matters worse, due to fast urbanization, population expansion, and trade liberalization in Africa, potential infrastructure upgrades may not be able to keep up with the pace of plastic waste generation (Kaza et al., 2018).

With an agreement scheduled for 2024 under the supervision of the United Nations Environment Program, there is currently no legally binding international treaty on plastic pollution as of 2023 September. With the exception of agreements indirectly related to other agreements like "Agenda 2063: The Africa We Want," "Agreement Establishing the African Continental Free Trade Area," "Africa Blue Economy Strategy," "African Union Plastic Pollution Initiative," and "Durban Declaration," the African Union (AU) does not currently have any regional Multilateral Environmental Agreements (MEAs) on plastic pollution (Sadan and de Kock, 2022). Only one of the sub-regional organizations, the East African Community (EAC), passed the "East African Community Polyethene Materials Control Bill, 2016" in 2017. The measure supports sustainable packaging and recycling while proposing a one-year ban on single use plastics bags. However, it excludes plastic used for furniture, household items, and industrial packaging. Every nation in East Africa has since implemented plastic laws. Research has shown that 12 of the 16 countries that make up the Economic Community of West African States (ECOWAS) and 10 of the 16 states that make up the Southern African Development Community (SADC) have plastic policies (Bezerra et al., 2021).

Plastic waste is a serious problem for the environment and the economy because it clogs waterways, wastes too much water, and has negative economic effects. By giving mosquitoes a place to remain wet, it also aids in the transmission of illness. Plastic bags harm the environment because they are lightweight. Botswana, Uganda, Kenya, and Zimbabwe are among the African nations impacted by plastic pollution. Oftentimes, plastic is mistaken for food by animals and livestock, which can be fatal. In 2015, the accumulation of plastic waste caused flooding and infrastructural damage in Accra, Ghana. Plastics disrupt entire food chains in marine habitats, slowing animal digestion and perhaps absorbing chemicals that cause cancer. This paper focuses on the effectiveness of Plastic Waste Management Policy in Africa

METHODOLGY

This paper which used a systematic review of literatures relied heavily on secondary data as is the case with most desktop study where existing information are used for analysis and to draw vital conclusions. The literature review process (see Figure 1) comprises three stages: searching for relevant sources using keywords, filtering them and collecting data as described by Thapa et al., (2023). It is for these reasons that the present paper utilized this approach to examine the success rate of policies implemented on plastics in Africa.

Figure 1: Process of articles selection

Findings

The summary of the findings on effectiveness of plastic waste management policy in Africa is provided in Table 1.

Table 1: summary of the findings on effectiveness of plastic waste management policy in Africa

Authors	Findings
Deme et al., (2022)	They highlighted significant policy-related obstacles in Africa's micro plastic management. The majority of the continent's nations have taken action, such as outlawing the use of single-use plastics for bags, but they first point out that these laws are ineffective because neither businesses nor customers will comply. The public and private sectors do not coordinate well, which brings us to our second point. Thirdly, the absence of pricing and other regulatory incentives that could influence how waste is disposed of; to put it plainly, plastics continue to be more affordable and practical.
Behuria (2019), UNEP (2018)	Contends that African nations are mostly driven to enact plastic restrictions in order to preserve their favorable reputations with Western tourists. Paper and cloth bags are more expensive to create, therefore local enterprises who provide substitute materials find it difficult to compete with the lack of enforcement of the plastic ban and the absence of assistance for recycling. The confluence of conflicting pressures from various sectors, such as tourism and outside activists, to local plastics and, more significantly, food and beverage manufacturers, can therefore be used to explain governments' hesitancy. Regulation does not have the necessary backing from the local populace to be implemented in a way that is sustainable. For instance, no stakeholder participation occurred

	when Rwanda banned plastic, and the availability of recycling technologies and alternative materials did not improve. People started bringing in plastic bags illegally from nearby nations as a result.
Behuria (2021), Chitombe (2014)	The foundation of the plastics industry's corporate power is in its ability to cater to several industries, one of which is tourism, which is a major user of plastic bags. Kenya's manufacturing sectors had a lot more clout in delaying the ban at first. Nevertheless, in 2018, the Kenyan government overrode such objections because it was worried about the country's reputation for environmental degradation in relation to tourism. The petroleum industry's dominance in Uganda contributes to the country's inability to enact such a ban supports this analysis by pointing out that the plastic levy in Zimbabwe has failed since the public does not accept it and it fails to take into account the urgent requirements of the informal sector. Even if implemented, the bag fee is insignificant, and there is a lot of bag smuggling in from nearby Mozambique.
Behuria, (2021); Chitotombe, (2014); Pensulo, (2019)	A number of industry stakeholders in Sub Sahara Africa also fiercely oppose public authorities, preventing or hindering the deployment of plastics intervention policies. Plastics producers can use their structural power to counteract plastic prohibition regulations because of the great demand for jobs in emerging nations. Plastic manufacturers and their associations have been fighting against plastic ban policies in Southern and East Africa, citing factors such as job losses, business closures, lost export revenue, and increased operational costs for other local manufacturers. Manufacturers' associations in Kenya and Uganda have built significant pushback with these arguments. Policy attempts in Kenya have faced comparable obstacles.
Shipton & Dauvergne (2021).	Because there is poor sanitation in rural regions, people defecate using plastic bags, which prompted the Ministry of Health to start looking into alternatives in 2004. A motion to switch to sisal bags from plastic was then passed by Parliament. Plastic bags with a maximum thickness of 0.03 mm were banned in 2007 and then increased to 0.06 mm in 2011. Kenya and the East African Legislative Assembly for the region banned plastic bags in 2017. The Kenyan Association of Manufacturers countered that enforcement would result in the loss of 70,000 jobs and serious financial difficulties for many businesses. In 2018, industry successfully lobbied against government attempts to ban single-use plastics altogether. As such, the region's norm diffusion and enforcement continue to be curtailed.

Kombiok et al. (2021)	In addition to the absence of fundamental waste infrastructure and collection services, they highlight behavioral barriers. 63% of Tamale, Ghanaian households were found to be disposing of plastic in an unsafe manner, and the researchers hypothesize that both wealth and education were contributing factors. They view public education as a crucial component of any solution package, in addition to the enforcement of regulations and the supply of alternatives. When South Africa's government started charging for plastic bags in 2003, there was a brief drop in their use. However, after three months, the fee for bags was eliminated because plastic bag producers objected.
Stoler et al. (2015) and Dikgang et al., (2012)	They discovered comparable behavioral issues in Ghana. They note that even when people living in urban slums had access to piped water, they still tended to favor buying packaged water in the form of "sachets." The changes in South Africa affected low-income groups significantly than how similar charges were perceived in the European Union. Even if total usage is down, it seems that consumers are, at least at the level of the rates set, prepared to pay the additional fees rather than utilize alternatives like cloth bags.
Iroegbu et al. (2020)	The issues in South Africa are summed up as follows: Three factors weaken regulation: (a) a lack of environmental values among the populace; (b) systematic corruption and political patronage systems; and (c) a dearth of efficient waste management solutions, such as recycling and waste treatment.
Deme et al. (2022)	They assert that the majority of African nations lack well-defined frameworks for managing plastic waste, which could compromise environmental and public health considerations while also addressing socioeconomic issues. They pointed out that, given the absence of facilities in the majority of African nations, wastewater treatment plants are probably the main source of micro plastics. Over 16 nations have outlawed the use of plastic bags, while about 34 countries have outlawed single-use plastics. However, plastics manufacturers have carried on as before. Sorting and recycling require very little work; estimates place the amount of plastic waste recycled at 10%. To put it plainly, the continent does not have a significant plastic recycling sector. As a result, the majority of waste gets burned, dumped into waterways, or disposed of in landfills. Furthermore, not much good work has been done to involve players in the circular economy who could identify new applications for plastics or to research and support alternatives that deal with socioeconomic issues

CONCLUSION

To lessen the negative consequences of plastic waste, several African nations have passed plastics-related laws. But there are challenges in implementing the policy framework in Africa. The absence of alternatives, inadequate or inconsistent monitoring and enforcement, and a lack of stakeholder participation were all noted as barriers to the effectiveness of the policies in Africa. The handling of plastic waste has been impeded by all of these characteristics, making it less sustainable. For transparency's sake, plastic regulations ought to be founded on reliable approaches that are made clear to the general public. Prior to the enactment of laws, a system for including stakeholders should be established. Environmentally friendly products like cotton, raffia, and leaf bags should be manufactured by private companies. In order to maintain a clean environment, governments must shift from enforcing rules and regulations to making deliberate decisions based on an awareness of public behavioral trends. To inform consumers and merchants about the harmful effects of plastic, law enforcement should conduct routine monitoring and a strategy that combines a widespread education campaign to change values with new policies.

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ARTIFICIAL INTELLIGENCE-BASED MAPPING OF CROPLANDS IN OYO STATE, NIGERIA

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ABSTRACT

Understanding cropping patterns and identifying farm characteristics in agricultural fields is crucial for optimising crop management practices and building a sustainable food system. Manual observation of farmlands in evaluating crop conditions and overall yields is time-consuming and labour-intensive for both small and large-scale farming areas. Hence, the adoption of artificial intelligence (AI)-enabled techniques in this research helped to accelerate the assessment of croplands and land agricultural uses. The objective of the study was to identify and profile crop type and cropping patterns of the farmlands in selected Local Government Areas in Oyo State. A two-stage sampling technique was utilised. Data collection using GoPro camera, mounted on a vehicle, was carried out in 2022 and 2023 across four purposively selected Local Government Areas of Oyo State – Atiba, Oyo West, Iseyin and Itesiwaju. The ArcGIS software was used for the digitization of farmlands as polygons leveraging on geo-referenced images obtained from the GoPro camera. Total land area covered was 257.87ha and 307.64ha, identifying 11 and 6 crop types in 2022 and 2023 respectively. The results of the study would be useful in enhancing improved agricultural livelihoods, sustainable food system and overall economic development in Oyo State, Nigeria.

Key words: *Cropland mapping, Sustainable agriculture, Crop type identification, Geographic information system, Digitization*

INTRODUCTION

Agriculture remains a vital sector in the Nigerian economy, contributing significantly to the nation's Gross Domestic Product (GDP) and serving as a primary source of livelihood for a substantial portion of the population (Osabohien *et al.,* 2020). Effective management of agricultural resources, particularly croplands, is crucial for ensuring food security, promoting sustainable farming practices, and enhancing rural development (Kassie *et al.,* 2015). In this regard, the mapping and characterisation of croplands play a pivotal role in facilitating informed decision-making and policy formulation (Dragović *et al.,* 2021). According to the Food and Agricultural Organization (FAO), the estimated croplands across the world in 2021 was 1.6billion hectares, while the average cropland area/person was estimated to be 0.2ha/capita, a decrease of 18% since year 2000. Cropland mapping and crop identification using traditional methods typically require labour-intensive field surveys and manual observation, which can be expensive, time-consuming, and prone to human error, particularly when working with large agricultural expanses (Belgiu and Csillik, 2018). As a result, there is an increasing demand for methods that are more precise and efficient for evaluating croplands and monitoring agricultural operations (Kamilaris and Prenafeta-Boldú, 2018).

Agricultural mapping and monitoring at present have become easier due to the development of Artificial Intelligence (AI) and sophisticated geospatial technologies, which have completely transformed the study and understanding of spatial data (Srivastava *et al.,* 2021). Utilising AI-enabled methods, scientists may accurately and at an unprecedented scale automate the processes of classifying crop varieties, drawing field borders, and assessing cropping trends (Kussul *et al.,* 2017; Guan *et al.,* 2020). In this study, mapping and classification of croplands in selected Local Government Areas (LGAs) of Oyo State, Nigeria was carried out, using an AI-enabled technology. The objective of the study was to identify and characterise crop types, draw field boundaries, and examine cropping patterns across the study area using cutting-edge geospatial technologies and techniques. The findings of this research would assist in the economic planning of Oyo State, as well as other regions to improve agricultural planning, sustainable resource management, and increase food security.

METHODOLOGY

This study employed a geospatial analysis approach using artificial intelligence techniques to map and characterize croplands in selected Local Government Areas of Oyo State, located in the south-western part of Nigeria. A two-stage purposive sampling technique was adopted for data collection. In the first stage, the study selected four Local Government Areas (LGAs) - Iseyin (latitude 7° 58' 35.37" N and longitude of 3° 35' 29.02" E), Itesiwaju (Latitude 8° 12' 25.74" N and Longitude 3° 31' 49.04" E), Oyo West (latitude 7° 51' 9" N and longitude 3° 55' 52" E) and Atiba (Latitude 7° 33' 28" N and Longitude 3° 59' 56" E), see Figure 1. These Local Government Areas were selected based on their significant agricultural activities and diversity of crop types.

The second stage involved systematic sampling of croplands within these Local Government Areas for data collection. This study used a GoPro Hero 8 Black camera. This camera was used in data acquisition (images of croplands) which was carried out in September of 2022 and 2023. The Camera was mounted on a vehicle where it takes an image every 0.5 seconds, which provides high resolution efficient and cost-effective approach for crop mapping fieldwork. The GoPro camera also captured geo-referenced images of croplands along pre-determined routes within the selected Local Government Areas. This approach was adopted to ensure a comprehensive coverage of the study area while minimizing time and labour requirements compared to traditional field surveys.

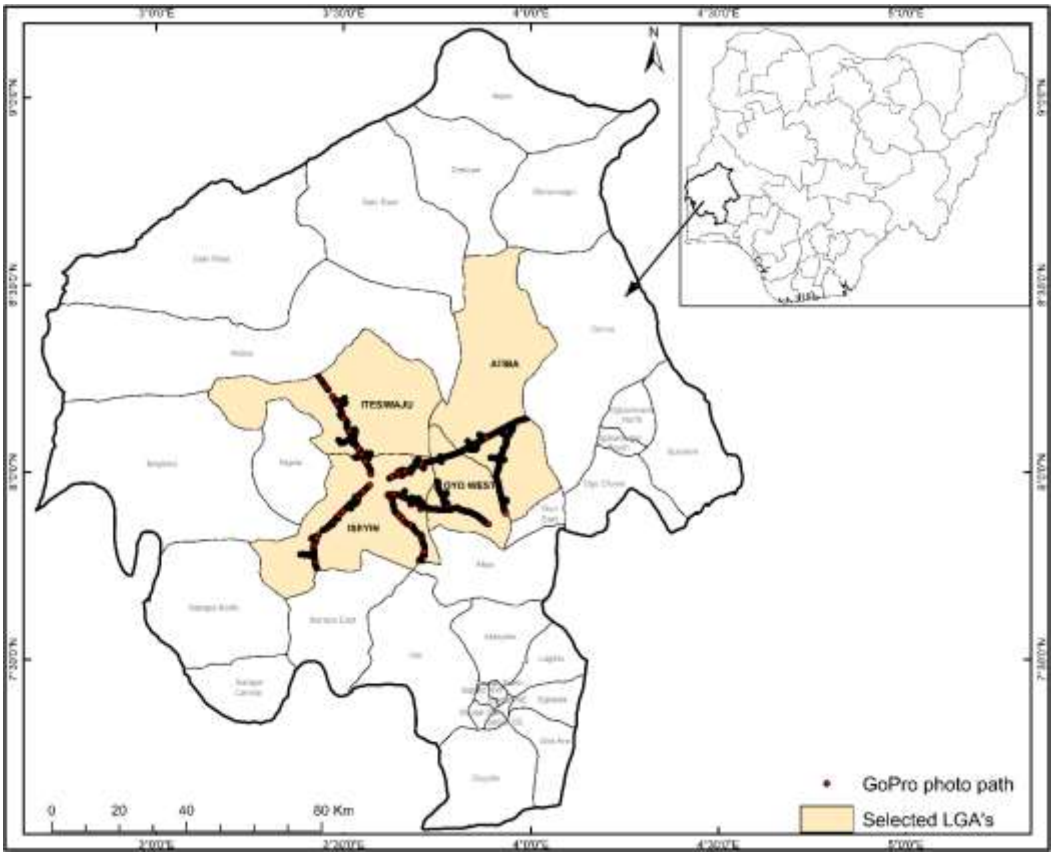

Figure 1: Map of Oyo State indicating the Study Area and GoPro Photo paths.

The collected images were then processed using ArcGIS software and the croplands were digitized as polygons using the already georeferenced information embedded in the images. This process gave a precise layout and spatial analysis of the croplands. To identify and characterise the crop type, the digitized polygons were further analysed based on visual interpretation of the images in the ArcGIS software, and the crop types were manually classified and labeled for each polygon. The cropland areas were further quantified, and the cropping patterns were analysed by exporting the dataset to Microsoft Excel. Pivot tables were employed to calculate the total land area (in hectares) covered, as well as the individual and accumulated land area for each identified crop type. This analysis was carried out to provide insight into the distribution and prevalence of different crop types across the study area.

In other to identify cropping patterns, croplands were analysed by examining the spatial distribution of the crop type within the study area. This analysis provided insights into crop rotations, intercropping practices, and the overall agricultural landscape in the selected Local Government Areas. The integration of the imagery, GIS techniques, and spreadsheet analysis allowed for efficient data collection, accurate cropland mapping, and detailed characterization of crop types and cropping patterns. Overall, this methodology allowed for rapid and accurate assessment of croplands, offering an effective and scalable solution for monitoring agricultural activities and supporting decision-making processes in the study region namely, the derived savannah and therainforest (Figure 1). The derived savannah comprises of woodland savannah coveringlocal government areas including, Saki East, Saki West, Irepo, Iseyin, Oyo East, Oyo West, Ogbomosho North and Ogbomosho South. It supports the cultivation of crops such as maize,yam, cassava, cashew, and soybean.

RESULTS AND DISCUSSIONS

The significant findings based on the agricultural activities of the farmers between the year 2022 and 2023 reveals various agricultural practices, cropping patterns, crop type diversity, and land area usage. The total land area mapped across the four (4) Local Government Areas and measured in Hectares (Ha) are shown in Figure 4.

Figure 2: Picture showing the digitized polygons and the images of the farmland

In 2022, Itesiwaju covered a total of 109.076Ha, Oyo West had 82.745Ha, Iseyin with a total of 66.149Ha an Atiba with 18.391Ha that were sampled. In 2023, total land area sampled in Iseyin was mapped to a total of 213.107Ha and Oyo West with a total of 56.663Ha.

The predominant crops in all four Local Government Areas between the 2022 and 2023 were Maize and Cassava (Figure 2 and Figure 3). In 2022, the total fields mapped in Itesiwaju were 141, Oyo West with 115, Iseyin with 38 and Atiba had 35. Meanwhile in 2023, the total field mapped in Oyo West was 147 and 202 in Iseyin. The presence of intercropped fields, such as Cassava-Maize, Maize-Soybean, Cassava-Pigeon Pea-Yam indicates the prevalence of mixed cropping practices which seek to improve food security and optimise land use.

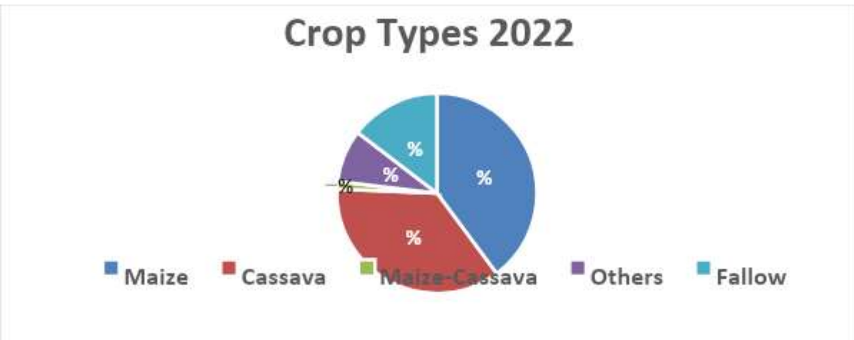

Figure 3: Pie chart showing the percentage of croptypes observed in 2022

The presence of other crops, figure 3, such as Groundnut, Yam, Soybean etc. suggests crop diversification and a dynamic agricultural environment. The result also further revealed agricultural practice of fallowing, which indicates land management aimed at the restoration of soil fertility.

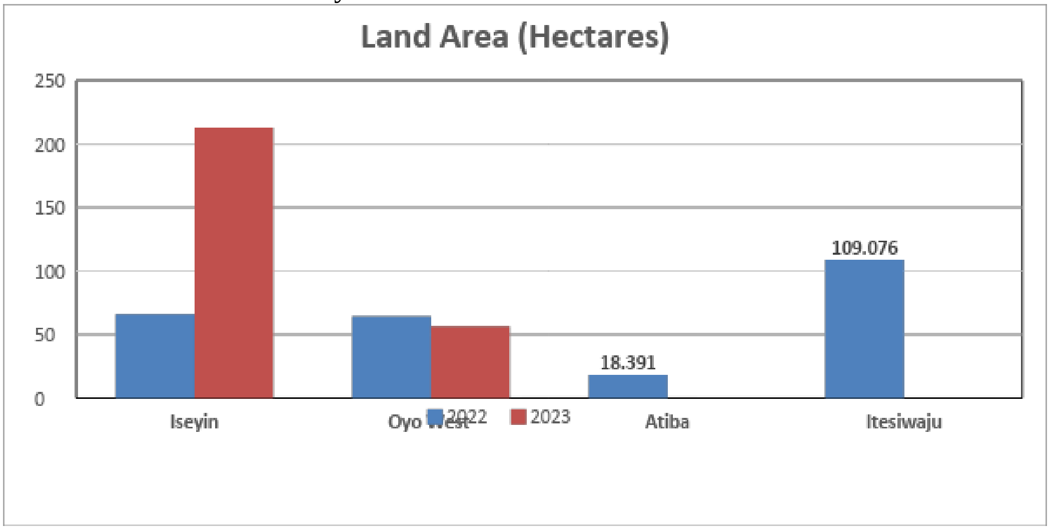

Figure 4: Bar chart showing total area of mapped farmlands from the year 2022-2023

CONCLUSION AND RECOMMENDATION

Cropland mapping is essential as it support agricultural planning, decision making and overall the economic development planning at all levels of governments. Farmlands from the selected four Local governments of Oyo State were sampled in which croptypes and cropping patterns were identified and analysed. Agricultural practices like fallowing were observed. These findings provide supporting evidences for farmers, policymakers, national and international organizations in planning aimed at reducing the risks to food security. Further studies should be carried out on cropland mapping in these areas including a comparative analysis method. This would be made possible if mapping is carried out using the same farm routes in both years for more accurate results.

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PRODUCTION, CHARACTERIZATION, AND APPLICATIONS OF BRIQUETTE FROM CASHEW NUT SHELL BIO-CHAR

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ABSTRACT

A pyrolysis reactor of external diameter 60 mm and height 150 mm was designed, constructed, and used to pyrolyze cashew nut shell (CNS). Thermogravimetric (TG), proximate and ultimate analysis were applied to the CNS sample before the pyrolysis process. Proximate and ultimate analysis carried on the CNS showed that the sample had a high calorific value (29,775.48 kJ/kg) and volatile matter (88.83 wt.%). Briquette was produced from the CNS bio-char and then characterized (through proximate and ultimate analysis, SEM and XRS-FP analysis). Results from the proximate analysis of CNS bio-char and briquette showed that the briquette had a calorific value of 29,553.55 kJ/kg, while from the XRS-FP analysis it was observed that the samples are made up (at varying concentrations) of compounds like: SiO_2, Fe_2O_3 CaO, Al_2O_3, Cl_2, and SO_3, and elements such as: Na, Al, Si, K, Ca, Fe. Both the compounds and elements are important sustainable ingredients in many chemical industries.

Key words: *Pyrolysis, Biofuel, Briquette, Renewable Energy, Sustainable development, CNS Bio-char*

INTRODUCTION

At a time when global warming and the fast depletion of nonrenewable energy sources are becoming everyone's concern, researchers must gear their researches toward attending sustainable solutions to these global issues. There is an increasing pressure on researchers to develop innovative technologies and energy wellspring that would help replace and reduce the use of fossil fuels (thereby minimizing greenhouse gases emissions). To achieve this, the development of these technologies must be economical and environmental friendly (to ensure sustainability) [1][2]. Plastic waste management is a big challenge to most countries in African countries. Worldwide, About 5 trillion of plastic bags are manufactured every year [3]. The process of manufacturing plastics and its disposal through burning/incineration is harmful [4] to workers, farmers [5], and among the primary causes of climate change[6]. Renewable energy sources such as solar, biomass, wind, and geothermal are abundant in nature (making them the closest alternative energy sources)[7]. Biomass is one of the important sources of renewable energy. Bio-briquettes made from green waste and other organic materials, is commonly used for electricity generation, heat, and cooking fuel.

Developing countries encounter dual crises of increasing energy demand and deforestation, which pose significant load on the environment. Forests act as an important ecological regulator of climate change, meaning deforestation will have a devastating impact on many social and economic activities [8]. In most of these countries, deforestation is an escalating problem (see Plate 1) especially in rural areas and among a higher number of the poor urban population. This problem is mostly caused by the consumption of traditional types of fuel (fire wood and charcoal)[9]. For example, the usage of traditional types of fuels by domestic cookers, is among the main causes of domestic air pollution in Senegal[10]. Data from the World Health Observatory estimates that about 7904 deaths recorded in Senegal was as a result of household air pollution [43]. According to the national survey of the 2nd project of participatory and sustainable management of traditional and substitute Energies [44], above 6 million cubic meter of wood are consumed as domestic fuel yearly in Senegal [45]. Furthermore, only about 36% of the Senegalese population have access to clean fuels and technologies for cooking [46]. In addition, approximately 7.2 million households in Kenya use biomass (traditional Energy source) as the main energy source (with charcoal making up to 13.3%, while wood fuel 68.7%). Only a small fraction of the Kenyan households (approximately 1.6 million households) makes use of energy sources like paraffin, liquefied petroleum gas (LPG), and electricity for cooking and heating [47]. About 45% of the total biomass energy resource is from the forests and woodlands which takes approximately 7% of the country's land. In Africa, until 2014, traditional fuel (firewood and charcoal) accounts for about 70% of the energy consumed [48]. [49]The use of agricultural waste in Africa to produce clean cooking energy is one of the possible alternatives to reduce the load on natural forests and combat domestic air pollution. Biomass briquette demonstrates an opportunity for economical and clean while generating income and creating employment opportunities [50].

Cashew nut is a multifunctional tree with much economic significance to some African countries, countries like: Benin Republic, Cote d'Ivore, Guinea Bissau, Ghana, Mozambique, Nigeria, and Tanzania [11]. For example, Nigeria's annual cashew nut production increased from 466,000 MT in 2000 to 836,500 MT in 2012. Cashew farmers in Nigeria earned N123 billion ($402 million) from the export of cashew in 2017, and between 2015 and 2017, they earned N284.5 billion ($813.05 million) in foreign exchange from the export of cashew. In 2018, Nigeria was ranked the 4th largest producer of cashew nut in the world [12]**.** The disposal of cashew nut shell by cashew nut industries in Africa, poses a huge challenge. Even when the shell is disposed by means of burning, it produces acid fumes (which are harmful to both humans and the environment)[13].

Pyrolysis is a thermochemical treatment process applied to organic (carbon based) materials at high temperatures [14]. This treatment process involves both chemical and physical separations, is carried out in the absence of oxygen/air [15]. Pyrolysis is an endothermic process that occurs typically at high pressures and temperatures (above 430 ^{o}C), and is not a reversible process [16]. Figure 1 shows a pyrolysis flow diagram. Bio-char is a form of solid residue produced by the exposure of organic matter to heat in an environment with low or no oxygen. In agriculture, it is used to amend the soil [17].

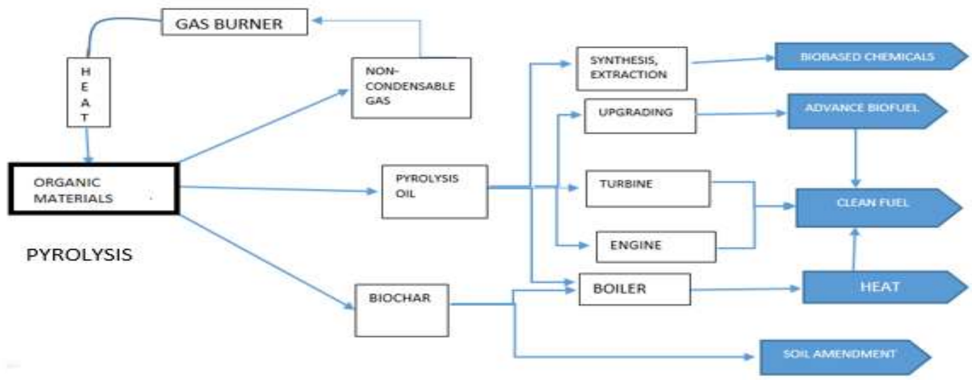


Figure 1: Pyrolysis flow chart

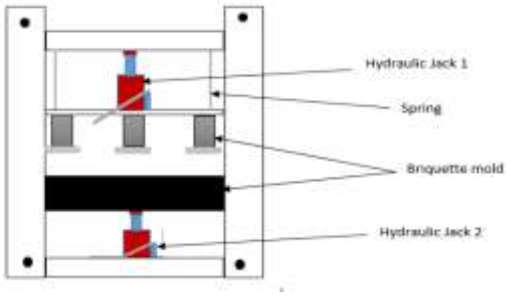
Plate 1: Images of deforestation (Captured on the 31/06/2023 @ Dimako, Eastern Region, Cameroon)

MATERIALS AND METHODS

Materials

Cashew nuts were obtained from Opi market, Nsukka Local Government Area, Enugu state, Nigeria. The nuts dried for two weeks using a solar crop drier (at the National Centre for Energy Research, University of Nigeria, Nsukka). To ensure a higher percentage of dryness, the nut shell was separated from the kernel (using a hammer). The separated shell was dried again for three weeks. The choice of a solar drier over other drying methods was based on economic reasons. The main ingredient CNS Bio-char (see

Plate 2) was obtained by the means of fast pyrolysis (600 – 800 ˚C) using a semi-batch pyrolysis reactor [18]. Other materials used were; Binder (starch), Bio-briquettes press machines



Methods

The CNS bio-char obtained from the fast pyrolysis process was ground and sieved to a particular size (of about 4 mm). After grinding, the char was then mixed with water and binder (starch) so as to form a paste. The paste was compressed using a briquetting machine, then dried for 7 days. Figure 2 is a briquetting machine, while Plate 3 shows an image of the produced briquette. The briquette was produced in collaboration with the National Centre for Energy Research, University of Nigeria, Nsukka. After production, the briquette was tested (as shown in plate 4). Plate 5 shows ash produced after the briquette was completely burned.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RESUALTS AND DISCUSSION

1. TGA and DTA Analysis

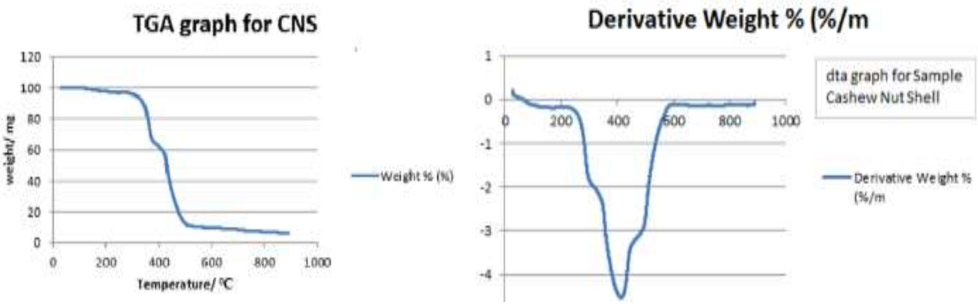


Figure 3: a) TGA Thermogram for CNS, b) DTA Thermogram for CNS

Proximate and Ultimate Analysis

Table 1. Proximate analysis of CNS, CNS Bio-char, and briquette

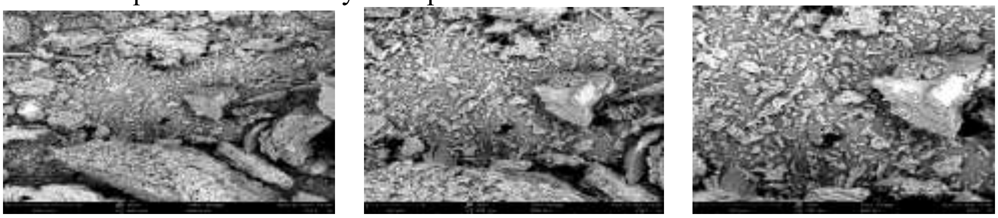
	CNS (wt. %)	CNS bio-char (wt. %)	Briquette (wt. %)
Moisture content	8.98	6.77	7.94
Volatile matter	88.83	88.44	78.74
Fixed carbon	0.12	7.90	9.33
Ash content	2.07	1.89	3.79
Calorific value (kJ/kg)	29,775.48	30,635.48	29,553.55

Table 2: Ultimate (Elemental) analysis of CNS and CNS bio-char

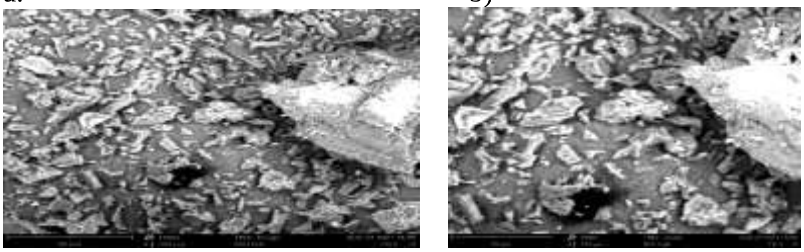
	CNS (wt.%)	CNS bio-char (wt.%)
Carbon, C	64.64	54

Hydrogen, H	7.39	7.73
Nitrogen, N	0.510	0.323
Sulphur, S	0.36	0.320
Oxygen, O	25.39	36.057

3. Briquette's SEM analysis Report



a. b) c)



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4. Briquette's XRS-FP Analysis Report

Table: 3: Compounds present in the Briquette sample

CrossRoads Scientific XRS-FP Analysis Report

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Layer Table

#	Thick	Type	Error	Units	Density	Norm.	Total
1	0.00	Bulk	0.00	mg/cm2	0.00F	On	100.00

Sample Table

Layer	Component	Type	Concn.	Error	Units	Mole%	Error
1	SiO2	Calc	9.111	0.810	wt.%	12.389	1.102
1	V2O5	Calc	0.026	0.047	wt.%	0.012	0.021
1	Cr2O3	Calc	0.393	0.038	wt.%	0.211	0.021
1	MnO	Calc	0.735	0.036	wt.%	0.847	0.042
1	Fe2O3	Calc	16.051	0.113	wt.%	8.212	0.058
1	Co3O4	Calc	0.149	0.039	wt.%	0.050	0.013
1	NiO	Calc	0.055	0.028	wt.%	0.060	0.030
1	CuO	Calc	0.636	0.028	wt.%	0.653	0.029
1	Nb2O3	Calc	0.050	0.015	wt.%	0.017	0.005
1	MoO3	Calc	0.025	0.017	wt.%	0.014	0.010
1	WO3	Calc	0.021	0.100	wt.%	0.007	0.035
1	P2O5	Calc	3.546	0.304	wt.%	2.041	0.175
1	SO3	Calc	2.933	0.214	wt.%	2.993	0.220
1	CaO	Calc	15.375	0.298	wt.%	22.400	0.431
1	MgO	Calc	0.000	0.000	wt.%	0.000	0.000
1	K2O	Calc	36.164	0.363	wt.%	31.367	0.315
1	BaO	Calc	0.000	0.000	wt.%	0.000	0.000
1	Al2O3	Calc	9.027	2.375	wt.%	7.233	1.903
1	Ta2O5	Calc	0.000	0.000	wt.%	0.000	0.000
1	TiO2	Calc	0.874	0.071	wt.%	0.894	0.072
1	ZnO	Calc	0.358	0.023	wt.%	0.355	0.023
1	Ag2O	Calc	0.026	0.048	wt.%	0.009	0.017
1	Cl	Calc	4.437	0.128	wt.%	10.226	0.296
1	ZrO2	Calc	0.014	0.015	wt.%	0.009	0.010

Table 4: Elements present in the CNS Briquette sample.

Element Table

Elmt	Line Code	Cond Code	Ratio Method	Intensity (c/s)	Error (c/s)	Intensity Method	Conc.	Conc Method	Calibration Coefficient
O	Ka	0	None	0.000	0.0000	Gaussian	29.139	None	0.000
Mg	Ka	1	None	0.000	1.1508	Gaussian	0.000	FP	0.000
Al	Ka	1	None	6.768	1.7808	Gaussian	4.778	FP	0.000
Si	Ka	1	None	33.378	2.9692	Gaussian	4.259	FP	0.000
P	Ka	1	None	40.199	3.4480	Gaussian	1.547	FP	0.000
S	Ka	1	None	57.076	4.2025	Gaussian	1.175	FP	0.000
Cl	Ka	1	None	265.973	7.6927	Gaussian	4.437	FP	0.000
K	Ka	1	None	2036.395	20.4360	Gaussian	30.022	FP	0.000
Ca	Ka	1	None	607.213	11.6953	Gaussian	10.989	FP	0.000
Ti	Ka	1	None	56.558	4.5747	Gaussian	0.524	FP	0.000
V	Ka	1	None	2.187	4.0325	Gaussian	0.014	FP	0.000
Cr	Ka	1	None	53.702	5.3018	Gaussian	0.269	FP	0.000
Mn	Ka	1	None	136.102	6.7243	Gaussian	0.569	FP	0.000
Fe	Ka	1	None	3282.777	23.1943	Gaussian	11.227	FP	0.000
Co	Ka	1	None	38.020	9.9101	Gaussian	0.109	FP	0.000
Ni	Ka	1	None	13.925	7.0484	Gaussian	0.043	FP	0.000
Cu	Ka	1	None	190.808	8.4412	Gaussian	0.508	FP	0.000
Zn	Ka	1	None	120.801	7.9822	Gaussian	0.284	FP	0.000
Zr	Ka	1	None	5.238	5.8582	Gaussian	0.010	FP	0.000
Nb	Ka	1	None	19.381	5.7774	Gaussian	0.039	FP	0.000
Mo	Ka	1	None	8.166	5.5506	Gaussian	0.017	FP	0.000
Ag	Ka	1	None	2.143	3.9627	Gaussian	0.024	FP	0.000
Ba	La	1	None	0.000	4.2654	Gaussian	0.000	FP	0.000
Ta	La	1	None	0.000	8.6484	Gaussian	0.000	FP	0.000
W	La	1	None	1.903	9.0760	Gaussian	0.017	FP	0.000

Analysis Conditions

#	Target	Filter	Thick. mg/cm2	kV	uA	Detector Type	Detector Filter	Thick. mg/cm2	Atm	Preset Time(s)	Actual Time(s)
1	Rh	None	0.00	35.0	30.0	SDD	None	0.00	Air	60.0	60.0

Processing Conditions

#	No. Smths	Escape Peaks	Sum Peaks	Back Type	C/R Ratio	Blank Rem.	Blank File
1	1	Yes	Yes	Auto	No	No	

DISCUSSION

1. TGA and DTA

As shown in Figure 3a, There is a small weight loss from room temperature to about 120 ^{o}C (due to the loss of moisture from the samples)[19]. The degradation process was greatest at approximately 148 ^{o}C to 494 ^{o}C as shown in Figure 3a. This high degradation temperatures are due to main chain pyrolysis [20]. From temperature 323.75 to 380.43 ^{o}C is the thermal decomposition starting point for CNS' constituents (hemicellulose and cellulose), also a thermal breakdown of the side chain and some fragments like CH_3 and OH radicals [21]. From 380.43 to 494.6 ^{o}C, the greatest degradation process took (due to the breakdown that occurs at the CNS matrix). Temperature of 437.62 ^{o}C is the starting point for lignin degradation as reported by [22]. The DTA thermogram in Figure 3b shows that, cashew nut shell has a higher melting point (about 350 - 405.5 ^{o}C). It was observed during the experiment that at temperature 350 ^{o}C, vapor started evolving into the condensing unit (confirming the result of the DTA plot). The TGA and DTA results helped in selecting the heating temperature levels [18].

2. Proximate and Ultimate Analysis

Table 1 shows the proximate analyses of the CNS, CNS bio-char, and briquette samples, and Table 2 gives the results from the ultimate analysis of CNS and CNS bio-char. A high calorific value (30,635.48 kJ/kg) makes the char a good source of energy. Looking at Table 1, it can be seen that the calorific value of the char is higher than that of the briquette (this can be attributed to the lower moisture content of CNS bio-char). The low ash and fixed carbon contents are indications the char is very combustible (as seen in plates 4 and 5 above). Table 2 shows the different amount of Nitrogen, Sulphur, and Oxygen as contained in the CNS bio-char. The high percentage of Oxygen in the briquette shows that the briquette is very combustible. Nitrogen and Sulphur are considered impurities and so must be removed or reduced to negligible amount. With the low amount of Nitrogen and Sulphur as seen in Table 2, it implies the CNS bio-char is environmentally friendly.

3. XRS-FP Analysis Report

XRS-FP analysis software is a quantitative analysis package for X-Ray fluorescence (XRF). XRF analysis with fundamental parameters (FP) converts elemental peak intensities to elemental concentration or film thicknesses. It processes the raw X-ray spectra measured to obtain;

1. The elemental peak intensities (the intensity of the peaks corresponding to each element)
2. The elemental concentration or film thickness [23] (CrossRoads Scientific).

   Thable 4 shows that the bio-char used for this briquette production is made up of very important compounds. The compounds are recorded in terms of their intensity and concerntration. It can be seen that the sample was composed more of K_2O (with a concerntration of 36 %). Other compounds that had significant concerntration were; $SiO_{2,}$ Fe_2O_3 CaO, Al_2O_3, Cl, SO_3 etc. (Table 4). Potash refers to different K-bearing minerals used in the production of fertilizer: Potash is comercialized on the basis of its oxide especially in the K_2O equivalent content. K_2O is widely used in the production of fertilizer [25]. SiO_2 (Silica (sand) is among the most common and abundant minerals on earth. Silica is used to produce glass wares, optical fibre, cement [26], and food additive (anticaking agent) [27]. Fe_2O_3 (iron(III) oxide or ferric oxide or hematite or rust etc.) is one of the ingredients used in the production of cement, and is the main source of iron in the steel industry. CaO (lime) on the other hand is an alkali, dough conditioner, yeast food [28], used in the production of cement [29], and is also used in the aluminium and steel industries (to remove silicate from the ore) [30] [31]. The sample also contained Al_2O_3 (Alumina) which is the most occuring of the oxides of aluminium. Alumina is used to produce fillers, cement, glass, catalysis, abrasive, paint [32], composite fiber, body armor etc. Looking at Cl (pale green), it is the 2nd lightest of the halogens, and its main common sources are sodium chloride (NaCl), potassium (KCl), and calcium ($CaCl_2$). Cl is used for sanitization, disinfection, antiseptics, bleaching agent and as a weapon of war (used in World War 1 by the Germans) [33] [34]. From the elemental table (Table 4.23), it shows that the briquette is made up of light metals (Na, Al, Si, K, Ca, Fe) which are enviromental friendly and are not harmful to the human system.

4. Scanning Electron Microscopy (SEM) Analysis

SEM is a tool which uses a focused beam of electrons to detect microspace and nanospace particles, up to the point where details and complexity that cannot be seen using the light microscopy can be revealed by SEM. It provides useful high resolution imaging of a sample's surface topography for evaluating various materials for; surface fractures, flaws, contaminants or corrosion [35] [36]. Looking at Figures 4a-4e, they show the briquette's surface morphology at different magnifications. The images show that the briqutte is made up of fine and porous particles attached to a smooth and non porous surface (the binder). The fine nature of those particles increase their binding strength and compactness during densification [37]; [38]; [39] [40]. Making use of small particle powder sizes in producing briquette is better than using big particle powder sizes, reason being that small particle sizes provide better mechanical properties compared to those with big particle sizes [41]. The porosity makes it posible for Oxygen to circulate through the briquette during combustion, (thereby causing it to be more combustive (as seen in plates 4 and 5 above)) [42]. Highly compressed briquettes give better mechanical properties than those that are less compressed. This is due to the fact that high compressing force enhances; abrasive resistance, impact resistance and compressive resistance (which are all enhancers of mechanical properties in biomass briquettes) [41].

CONCLUSION

The char (CNS char) was used to produce briquettes (a source of renewable energy). The characterization of the char and briquette showed that the char and briquette had high calorific values with good properties, making them potential energy sources. The CNS bio-char was found to contain potash (used for producing fertilizers), thereby making it good for agriculture (when used as a soil enhancer). From the XRS-FP results, it showed that the briquette/char was made up of very important elements and compounds that can be used in the cement industry, iron and steel Industries, food industry, agricultural industry, and many other chemical industries. The SEM results also showed that the briquette was well compacted, the char had fine and porous particle sizes. The process of pyrolysis can turn waste into wealth, for it is a process that produces little or no waste.

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ARTISTIC INTERVENTIONS: REDEFINING PLASTIC WASTE IN AFRICA THROUGH AN ART LENS

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ABSTRACT

Plastic waste management in Africa presents a complex challenge that demands innovative and multifaceted solutions. While existing research predominantly focuses on scientific and policy-oriented approaches, this paper proposes a novel perspective by examining the issue through the lens of art. By exploring the cultural, historical, and aesthetic dimensions of plastic waste, this paper aims to uncover alternative strategies for achieving healthy environment through sustainable waste management in Africa. Drawing on theories of visual culture, eco-criticism, and postcolonial studies, the paper situates artistic interventions within the broader discourses of environmental justice and sustainability. Through qualitative analysis of contemporary artworks, public installations, and community-based initiatives, the study elucidates the diverse ways in which artists engage with plastic waste as both material and metaphor. Case studies of prominent African artists and collectives, such as Serge Attukwei Clottey with his Afrogallonism, Konboye Eugene, Olanrewaju Tejuosho, Yusuf Durodola, and the "Flipflopi" Initiative in kenya, illustrate how artistic practices can provoke critical reflections, mobilize communities, and advocate for change. By reframing plastic waste as a cultural and aesthetic phenomenon, this paper advocates for the integration of artistic perspectives into environmental policymaking and advocacy efforts. Furthermore, it highlights the importance of decolonizing environmental discourse by centering African voices and knowledge systems in tackling the waste menace in the continent. Ultimately, this paper contends that visual art offers valuable insights and approaches for addressing the pressing environmental challenges facing Africa, paving the way towards a more sustainable and inclusive future.

***Key words**: Plastic waste, Africa, Art history, Environmental management, Sustainability, Cultural perspectives.*

INTRODUCTION

Plastic pollution is a pressing global environmental crisis, especially pronounced in Africa due to rapid urbanization, industrialization, and inadequate waste management infrastructure. With the continent's population projected to reach 2.5 billion by 2050, the current 1.36 billion inhabitants already face significant challenges exacerbated by insufficient waste management systems and widespread use of single-use plastics.

Presently, plastics constitute 13% of Municipal Solid Waste (MSW) in Africa, while organic waste makes up 57%, much of which is dumped rather than utilized for its potential socio-economic benefits. Projections indicate a tripling of waste volumes by 2050, reaching an estimated 516 million tonnes annually across the continent. Amidst this crisis, artistic interventions emerge as beacons of creativity and resilience. Artists not only raise awareness about plastic pollution but also offer innovative perspectives on redefining plastic waste, showcasing the crucial role of art and visual culture in reshaping perceptions and behaviors.

This study delves into the intersection of art, environmentalism, and cultural history in Africa, focusing on how artists engage with plastic waste. Through a visual art lens, the paper explores how artists across the continent confront, critique, and transform plastic waste into powerful narratives and symbols. From sculpture to community-based projects, diverse artistic practices illuminate the complex dynamics between materiality, representation, and environmental activism.

By situating artistic interventions within broader socio-political contexts, the study sheds light on how artists navigate issues of consumption, globalization, and ecological crisis while challenging dominant narratives and fostering alternative visions of sustainability and resilience. Ultimately, this research aims to contribute to scholarly discourse and practical interventions addressing plastic pollution in Africa. By showcasing the transformative potential of artistic practices, the paper inspires new approaches towards a more sustainable and equitable future for the continent and beyond.

Art and Environmentalism

The nexus of art and environmentalism has been a focal point in academic circles for decades. Scholars like Buergel and Weibel (2015) contend that artistic endeavors possess the capacity to disrupt conventional environmental narratives, offering fresh perspectives and avenues for engagement. Within Africa, research by Okely and Callan (2018) and Smith (2020) investigates how artists integrate environmental themes into their work, often drawing from indigenous knowledge and cultural traditions to confront ecological issues.

Art serves as a potent vehicle for raising consciousness, galvanizing action, and facilitating discourse on environmental challenges. Across Africa, artists have emerged as influential figures in addressing urgent environmental issues like plastic pollution, deforestation, and climate change. Notably, Okwui Enwezor's groundbreaking exhibition "All the World's Futures" at the 2015 Venice Biennale showcased African artists grappling with environmental concerns, spotlighting the continent's contributions to global environmental dialogue (Enwezor, 2015). Renowned artists like El Anatsui have garnered international acclaim for their use of recycled materials to craft monumental installations, shedding light on consumption and waste in African societies (Stevenson, 2009). Artistic interventions against environmental degradation extend beyond Africa to other continents. In Europe, environmental art movements burgeon, encompassing practices from land art to eco-feminism. Originating in the 1960s and 70s, the Land Art movement, spearheaded by artists like Robert Smithson and Andy Goldsworthy, emphasized the interplay between art, nature, and the environment (Kastner & Wallis, 1998). Presently, European artists harness digital technologies and multimedia platforms to confront climate change and ecological decline, engaging audiences in immersive experiences that provoke reflection and action (Burns, 2015).

Similarly, in America, a rich history of environmental art dating back to the 1960s features artists such as Agnes Denes and Robert Rauschenberg, who pioneered unconventional materials and site-specific installations to explore ecological themes (Taylor, 2016). The Earthworks movement, prominent in the American Southwest, saw artists like Walter De Maria and Nancy Holt integrating natural landscapes into their artistic endeavors (Kwon, 2002). Today, American artists continue to innovate, addressing urbanization, pollution, and biodiversity loss through interdisciplinary collaborations and community initiatives (Oppenheim, 2017). In Asia, artists respond to environmental challenges stemming from rapid industrialization and urbanization. Environmental art movements in countries like China and India underscore a growing awareness of the environmental toll of economic growth (Gardner, 2018). Figures like Ai Weiwei and Subhankar Banerjee utilize their art to advocate for environmental justice, spotlighting issues like pollution and climate change (Banerjee, 2016; Kuo, 2019). Moreover, traditional Asian art forms inspire contemporary artists seeking to reconnect with nature and promote sustainable living (Nakamura, 2008).

Artists across continents wield significant influence in shaping environmental discourse, challenging perceptions, and inspiring action through their creative endeavors. From Africa to Asia, Europe to America, the diverse array of artistic practices employed to address environmental concerns underscores the universal importance of art as a catalyst for positive change in our relationship with the natural world.

Plastic Pollution in Africa

Plastic pollution has emerged as a pressing environmental issue in Africa, adversely impacting ecosystems, public health, and socio-economic progress. Factors like rapid population growth and urbanization, coupled with insufficient waste management infrastructure, contribute to escalating plastic pollution levels (Jambeck et al., 2015; Amankwah-Amoah, 2020). Despite heightened awareness, effective solutions remain elusive, especially in regions lacking proper waste management facilities.

A significant portion of plastic waste, estimated at 4.8 to 12.7 million metric tons globally in 2010, originates from African countries (Jambeck et al., 2015). Widespread use of single-use plastics, inadequate waste disposal systems, and limited awareness exacerbate the problem (Cózar et al., 2017). The consequences span terrestrial and marine environments, contaminating water bodies, endangering marine life, and threatening human health through toxic chemical leaching (Lebreton et al., 2017; Worm et al., 2017). Addressing this crisis necessitates a multifaceted approach, including policy interventions, awareness campaigns, and innovative waste management solutions (Hoornweg et al., 2019). Measures such as plastic bans, producer responsibility schemes, and recycling incentives can mitigate plastic usage. Public awareness and community initiatives are vital for fostering sustainable behaviors, while investments in waste management infrastructure are crucial for minimizing environmental leakage (Hoornweg et al., 2019).

Concerted efforts from governments, civil society, and the private sector are imperative to combat plastic pollution effectively, promoting policies and practices that reduce consumption, enhance waste management, and foster environmental stewardship.

Artistic Responses to Plastic Waste

Artists worldwide are creatively responding to the plastic waste crisis, using their art to raise awareness, provoke thought, and inspire action. In Europe, diverse mediums such as sculpture, painting, and performance art are employed to explore plastic waste themes. German artist Ha Schult's "Trash People" series features life-size sculptures crafted from recycled materials, drawing attention to the issue (Schult, 2019). Collaborations like the Plastic Pollution Coalition's partnership with artist Mandy Barker produce impactful works like "Soup," which documents global plastic debris (Barker, 2018). American artist Chris Jordan's "Midway: Message from the Gyre" series captures the tragic effects of plastic pollution on wildlife (Jordan, 2011). Meanwhile, in New York City, Basia Goszczynska uses discarded plastic to create immersive installations (Goszczynska, 2020). In Asia, artists like Subodh Gupta and Yoshitomo Nara explore cultural and environmental dimensions of plastic waste through installations (Gupta, 2014; Nara, 2019).

Across continents, artists are employing creativity to address global plastic waste challenges. In Africa, Attukwei Clottey and Cyrus Kabiru repurpose plastic waste into sculptures, confronting consumerism and waste issues (Biennale de Lyon, 2019; Lebovich, 2019). These efforts reflect a broader trend of African artists using art to address plastic pollution's environmental impacts (Montana, 2019). African artists are motivated by a desire to raise awareness, challenge consumer culture, and advocate for sustainability (Tejuosho, 2020). Their diverse methods range from sculpture to community-based projects, as seen in Serge Attukwei Clottey's "Afrogallonism" series and Olanrewaju Tejuosho's "Eco Ethics" project (Montana, 2019; Tejuosho, 2020).

Artistic interventions have significant impacts on raising awareness and catalyzing action. By engaging audiences visually and tactilely, artists shift perceptions and behaviors regarding plastic consumption and disposal (Durodola, 2018). Community-based projects empower marginalized communities in waste management practices (Durodola, 2018). Artistic responses in Africa reshape narratives around plastic waste, advocating for a sustainable future.

Artistic Interventions in Plastic Waste Management in Africa

Artists across Africa play a pivotal role in advocating for a sustainable environment with reduced plastic waste, employing diverse approaches in engaging with the plastic waste theme within their practice. Figures like Serge Attukwei Clottey, Konboye Eugene, Olanrewaju Tejuosho, and Yusuf Durodola, along with community-driven projects like the "Flipflopi" Initiative, exemplify this multifaceted approach.

Serge Attukwei Clottey, through his "Afrogallonism" movement in Ghana, transforms discarded plastic jerry cans into impactful installations and performances. His art not only raises awareness but also empowers communities to reclaim their environment creatively, sparking critical reflections on the socio-economic and environmental impacts of plastic waste.

fig. 1

fig. 2

Courtesy: The Artist Instagram page, Serge Attukwei

Konboye Eugene, a Nigerian sculptor, focuses on aesthetics to address plastic pollution. By meticulously crafting salvaged plastic materials into intricate artworks, Eugene celebrates African ecosystems' beauty and resilience. His work challenges perceptions of waste and reframes plastic pollution as an opportunity for creative reimagining, fostering a deeper appreciation for the interconnectedness of human and natural systems.


fig. 3 fig. 4
Courtesy: The Artist Instagram page, Konboye Eugene

Olanrewaju Tejuosho engages communities in Nigeria through collaborative workshops and public installations, mobilizing grassroots action against plastic pollution. His initiatives not only raise awareness but also promote social cohesion and collective agency among marginalized communities, emphasizing the need for inclusive environmental activism.


fig. 5 fig. 6
Courtesy: The Artist Instagram page, Olanrewaju Tejuosho

Yusuf Durodola, also from Nigeria, employs visual aesthetics to shed light on the human and environmental costs of plastic pollution. Through powerful imagery and storytelling, Durodola captures the implications of unchecked plastic waste, particularly on future generations. His work confronts viewers with the stark realities of plastic pollution and advocates for greater accountability and solidarity in addressing its root causes.

 

fig. 7 fig. 8

Courtesy: The Artist Instagram page, Yusuf Durodola

In Kenya, the "Flipflopi" Initiative showcases the transformative potential of creative solutions to plastic pollution. Constructing a boat entirely from recycled plastic flip-flops, the project merges art, education, and advocacy to raise awareness and offer tangible solutions for repurposing waste materials and promoting sustainable livelihoods.

 

fig. 9 fig. 10

 

fig.11 fig. 12

Courtesy: Collectively, these artistic endeavors illustrate how creativity and innovation can inspire hope and resilience in the fight against plastic pollution, not only in Africa but also globally.

Situating Artistic Interventions within Environmental Discourses

Artistic interventions addressing plastic waste in Africa intersect with broader discourses of environmental justice, environmentalism, cultural activism, sustainable development, and cultural heritage preservation. Leveraging theories of visual culture, eco-criticism, and postcolonial studies, these interventions challenge dominant narratives and advocate for inclusive approaches to environmental policymaking and advocacy. Visual culture and eco-criticism frameworks illuminate how artistic representations of plastic waste engage with environmental justice and activism. Artists employ visual imagery to reveal the ecological impacts of plastic pollution, prompting viewers to reconsider their relationship with the environment (Mitchell, 2002). By critiquing consumerist culture and promoting sustainable living visions, artists advocate for alternative ecological ethics (Garrard, 2004). Postcolonial studies highlight historical colonial legacies underlying environmental degradation in Africa, advocating for decolonized environmental discourse by centering African voices and knowledge systems (Mbembe, 2001; Escobar, 2018).

Decolonizing environmental discourse involves centering African perspectives in environmentally sound plastic waste management. Challenging Western-centric paradigms, inclusive environmentalism recognizes the interconnectedness of social, cultural, and ecological systems (Escobar, 2018; Haraway, 1991). Collaboration with local communities and indigenous practitioners ensures inclusive strategies honoring traditional ecological knowledge and promoting environmental justice (Haraway, 1991). Artistic interventions contribute to sustainable development by fostering community resilience and eco-friendly practices. Repurposing plastic waste into art showcases creative reuse's potential, promoting resourcefulness in mitigating environmental harm (Buell, 2005). These interventions also underscore traditional practices' cultural significance in environmental stewardship and cultural heritage preservation (Haraway, 1991). Incorporating artistic perspectives into policymaking fosters more holistic and inclusive approaches to addressing plastic waste (Nixon, 2011; Shiva, 2016).

Artistic interventions reshape environmental discourse in Africa by challenging power dynamics, fostering cultural resilience, and advocating for inclusive environmental justice and sustainability. Amplifying African voices and knowledge systems, policymakers can develop contextually relevant solutions addressing plastic waste's socio-cultural dimensions, leading to more effective and sustainable outcomes.

In conclusion, artistic interventions redefine narratives and practices surrounding plastic waste in Africa, mobilizing resources, raising awareness, and advocating for change through creative expression. Incorporating artistic perspectives into policymaking ensures culturally sensitive and effective strategies, fostering community participation and empowerment. Implementing these recommendations harnesses art's transformative power, advancing sustainable and equitable environments for all.

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THE ROLE OF ARBUSCULAR MYCORRHIZAL FUNGI IN INCREASING NUTRIENTS UPTAKE IN AGRICULTURAL SOILS: A BIBLIOMETRIC REVIEW

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ABSTRACT

Through their symbiotic relationship with plant roots, arbuscular mycorrhizal fungi (AMF) play a vital role in enhancing nutrient uptake in agricultural soils. This bibliometric review aims to systematically analyze the existing literature on the topic, highlighting key trends, research areas, and gaps. By means of thorough bibliometric analysis, this review offers insights into the role of AMF in promoting soil health in agricultural systems and optimizing nutrient management strategies. Moreover, the findings of this review contribute to a deeper understanding of the role of AMF in optimizing nutrient management strategies and enhancing soil health.

***Key words**: Arbuscular mycorrhizal fungi, nutrient uptake, agricultural soils, soil health.*

INTRODUCTION

Most terrestrial plant species form symbiotic associations with arbuscular mycorrhizal fungi (AMF) at their roots (Wang & Qiu, 2006; Smith & Read, 2008; Brundrett et al., 2009). AMF is essential for the acquisition of nutrients from the soil, especially phosphorus (P) and nitrogen (N) (George et al., 1995; Hawkins, et al., 2000; Hodge et al., 2001; Smith & Read, 2008; Leigh et al., 2009; Bücking & Kafle, 2015; Xie et al., 2022). This symbiosis improves plant growth, improves nutrient uptake efficiency, and supports soil fertility and ecosystem functioning (Smith & Read, 2008). AMF's role in improving nutrient uptake in agricultural soils has been the subject of many studies due to its importance in agricultural systems (Smith & Smith, 2011; Miransari, 2013). The objective of this bibliometric review is to provide insights into the current state of research on this topic and identify future directions

METHODOLOGY

Using keywords related to arbuscular mycorrhizal fungi, nutrient uptake, and agricultural soils, a systematic search of academic databases (Web of Science and Scopus) was carried out; the search was restricted to peer-reviewed journal articles published in English up to March 2024. Bibliometric analysis was carried out using bibliometric softwares (VOSviewer and Bibliometrix) to identify key publications, authors, journals, and research trends.

RESULTS AND DISCUSSION

Research Trends

Key research areas include the mechanisms underlying AMF-mediated nutrient uptake, the impact of AMF on plant growth and yield, and the potential applications of AMF in sustainable agriculture. The analysis of research trends indicated a growing interest in the role of AMF in enhancing nutrient uptake in agricultural soils over the past few decades. The number of publications on the topic has increased steadily, indicating its significance in agricultural research

Key Findings

The bibliometric analysis generated several important conclusions, such as:

- AMF increases the surface area of plant roots and facilitates nutrient transport, which increases nutrient uptake in agricultural soils.
- Plants and AMF have a symbiotic relationship that affects soil fertility and nutrient cycling, which increases crop productivity and sustainability.
- AMF interact with various plant species in a species-specific manner, emphasizing the significance of comprehending the specificity of these symbiotic relationships.
- The use of AMF in agricultural practices like biofertilization and bioremediation has been studied, and the results are encouraging in terms of improving nutrient uptake and lowering the demand for chemical fertilizers.

Future Directions

Despite significant progress in understanding the role of AMF in enhancing nutrient uptake in agricultural soils, several knowledge gaps and future research directions remain:

- Further investigation into the molecular mechanisms underlying AMF-mediated nutrient uptake to optimize their use in agricultural systems.
- Long-term studies evaluating the sustainability and effectiveness of AMF-based interventions in diverse agricultural settings.
- Integration of AMF inoculation strategies with other soil management practices to enhance nutrient cycling and soil health.

- Exploration of the potential effects of environmental factors (e.g., climate change, soil degradation) on AMF-plant interactions and nutrient uptake processes.

Even though our understanding of how AMF improves nutrient uptake in agricultural soils has advanced significantly, there are still a number of unanswered questions and potential areas for further study:

- In order to maximize the utilization of AMF-mediated nutrient uptake in agricultural systems, more research into the molecular mechanisms underlying it is necessary.
- Long-term research assessing the efficacy and sustainability of AMF-based interventions in various agricultural ecosystems.
- Combining AMF inoculation techniques with other methods of soil management to improve soil health and nutrient cycling.
- Investigating the possible impacts of environmental problems such as soil degradation and climate change on AMF-plant interactions and nutrient uptake processes.

CONCLUSION

In conclusion, this bibliometric review provides a comprehensive overview of the role of arbuscular mycorrhizal fungi in enhancing nutrient uptake in agricultural soils. The analysis highlights the significance of AMF symbiosis in promoting soil fertility, crop productivity, and sustainability in agricultural systems. By identifying research trends, key findings, and future directions, this review serves as a valuable resource for researchers, practitioners, and policymakers working in the field of soil science and sustainable agriculture.

The analysis highlights the importance of AMF symbiosis in promoting soil fertility, crop productivity, and sustainability in agricultural systems. In summary, this bibliometric review offers a thorough overview of the role of arbuscular mycorrhizal fungi in enhancing nutrient uptake in agricultural soils. By identifying research trends, key findings, and future directions, this review serves as a valuable resource for researchers, practitioners, and policymakers working in the field of soil science and sustainable agriculture.

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EVALUATION OF POWDER AND OIL EXTRACT FROM GINGER, *ZINGIBER OFFICINALE (*R.), FOR THE CONTROL OF *CALLOSOBRUCHUS MACULATUS* (F.)

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ABSTRACT

Callosobruchus maculatus Fabricius (Coleoptera: Bruchidae) is an important primary insect pest of cowpea in the store causing considerable damage to the grains. In this study, the bio-activities of *Zingiber officinale* rhizome (Ginger) powder and oil extract were investigated against *C. maculatus*. The powder and oil extract of *Z. officinale* rhizome were screened in the laboratory against adult *C. maculatus* at different concentration (0g, 1g 2g, 3g, and 0ml, 1ml, 2ml and 3ml per kg of Cowpea seeds). The following data were collected: mortality, number of eggs laid, number of seeds with and without eggs, number of seeds with and without holes and emergence of adult *Callosobruchus maculatus*. The result showed that percentage survival of the insects was significantly reduced at higher concentration of the oil extract. The 2g and 3g of *Z. officinale* powder were the most effective and significantly caused 100% mortality of *C. maculatus* after 72 hours of treatment. There was no surviving *C. maculatus* recorded at 3ml of *Z. officinale* treatment. Seeds treated with the different concentration of *Z. officinale* oil extracts significantly repelled insects with the highest concentration of 3ml yielding 100% repellency to *C. maculatus*.

INTRODUCTION

Cowpea is commonly known as black-eye bean, catjang, or bachapin bean (Obeng-Ofori, 2007). It is one of the five most important legumes in the tropics and provides protein for most people and nitrogen to the soil. However, a wide spectrum of pest attack and destroy cowpea both in the field and in the store causing severe economic damage. Most importantly is the *Callosobruchus maculates* Fabricius (Coleoptera: Bruchidae) which is a cosmopolitan insect pest of cowpea (Obeng-Ofori, 2008). Grain damage in the store may reach up to 100% if these insects are not managed (Owusu-Akyaw, 1991). Umeozor (2005) reported that *C. maculatus* damage to cowpea could range between 10% - 50%. Their damage causes loss of weight, nutritional value and viability of stored grains. However, the bruchid, *Callosobruchus maculatus* (F.) which infest the seeds at storage assume special significance (Tran and Credland,1995) Therefore, to meet the demand of the ever growing population, man has employed several options in order to curb the damaging effect of these insects and hence increase food production. One of the mostly used control measure is the use of synthetic insecticide. Majority of the synthetic chemicals used by farmers to control the weevil infestation has the following setbacks:

How they affect the non-target species, pollution, cost, pest resistance and resurgence (Al Zaidi *et al.,* 2011). Considering the predominance of poor storage facilities and the economic load for resource-poor landholders, user and consumer safety issues, warn against the application of fumigants or synthetic insecticides for on-farm protection of stored crops. Thus, the use of botanicals or Bio-pesticides is encouraged.

Ginger root which is commonly called ginger is the rhizome of the plant *Zingiber officinale.* The proximate analysis of ginger shows that it contains 80.8% water, 2.3% protein, 1.0% fat, 12.3% carbohydrate, 2.4% fibre and 1.2% ash (Obeng-Ofori *et al*., 2007). It also contains 1% -3% of volatile oil, which is primarily made up of Sesquiterperne, Zingiberene, and Zingerone, which gives the pungent smell (Obeng-Ofori *et al*., 2007). Oil extract of ginger have been reported to exhibit toxic and repellent effects on *Prostephanus truncatus* Horn (Ogbonna *et al*., 2014).

MATERIALS AND METHODS

Source of material

The ginger (*Zingiber officinale*) was bought from Oja Oba, Nigeria. *Callosobruchus maculatus* was gotten from colony originating from infested cowpea seeds bought from FUTA South Gate which have been left to breed at laboratory temperature and relative humidity. Sokoto white variety of cowpea used for the experiments was obtained from same place and was sterilized using cooling method (5-7 days) to prevent pest infestation.

Sample analysis

An electric Soxhlet extractor was used in which the powder ginger was poured in a muslin cloth, placed inside the thimble and extractor solvent used was N-hexane, at heating temperature of 78^0C-82^0C for $6^{1/2}$ hours. Data on the Insecticidal and Ovicidal effect of ginger powder and oil extract were taken. Germination Test was carried out in the laboratory three (3) weeks after treatment in which tissue paper was folded in Petri-dishes and water was applied to create a wet substrate to facilitate germination. Number of radicle emergence were counted after 5 days of planting. Plumule emergence was counted and recorded after 10 days of planting. The mortality of the treatments was transformed using arc-sine transformation method, while other count data were transformed using square root transformation. The transformed figures were analyzed using Analysis of Variance and results were presented in tables. Minitab software version 17 was used. Means were separated using Tukey's test at 5% level of probability.

RESULTS AND DISCUSSION

The results obtained in this study were in line with the attributes of ginger as has been documented by many researchers (Iqbal and Paswal, 1995; Amer *et al*., 2003). Table 1 shows the effect of the treatment after they have laid eggs and there has been emergence. Ginger powder, at 3g proved to be very effective in the control of the eggs laid, thus reducing the population of emerged adults. The highest ginger concentration of 3g was compared with that of the ginger oil extract treated control. This trend was followed in the number of perforations observed in the seeds, but the ginger oil extract treated control was the best and thus differed significantly ($P<0.05$) with both the ginger treated and untreated control. On the rate of adult emergence, at 7 days after infestation, the treatments did not differ in their effects. At 2days (48hrs) after treatment, the ginger residue treated beans seeds started showing reduced adult *C. maculatus* emergence compared to the untreated grains such that there was a progressive decrease in adult emergence as the percentage concentration increases. This confirms the bio pesticidal property of the ginger powder and oil extract. The repellency property of the essential oil of the plant has been reported (Rabelo *et al.*, 2003). The use of plant materials is due to their availability, edibility and low records of human toxicity (Oni, 2014). The mortality of adult weevil may be linked to active compounds in the ginger powder and oil extract, which caused spiracle blockage, amongst other physiological stress on the insect (Adedire *et al.*, 2011; Fernando and Karunaratne, 2012; Sarwar *et al.*, 2012). After planting, the number of radicles and plumules were taken respectively after 5 days and 10 days. Seeds treated with ginger powder germinated and data were recorded, but for the seeds treated with the oil extract from ginger, it did not grow, aside the controls. It is because the ginger oil killed the embryo of the treated seeds.

Table 1: Insecticidal effects of ginger powder on *Callosobruchus maculatus.*

Conc. (grams)	Oviposition	Seeds with eggs	Seeds without eggs	Emergence	Seeds with holes	Seeds without holes
0	1.60a	1.90ab	4.23bc	1.00a	2.07a	4.17b
1	1.60a	2.13a	4.13c	1.00a	2.27a	4.07b
2	1.50a	1.70b	4.30b	1.00a	2.07a	4.17b
3	1.13a	1.13c	4.47a	1.00a	1.60b	4.33a

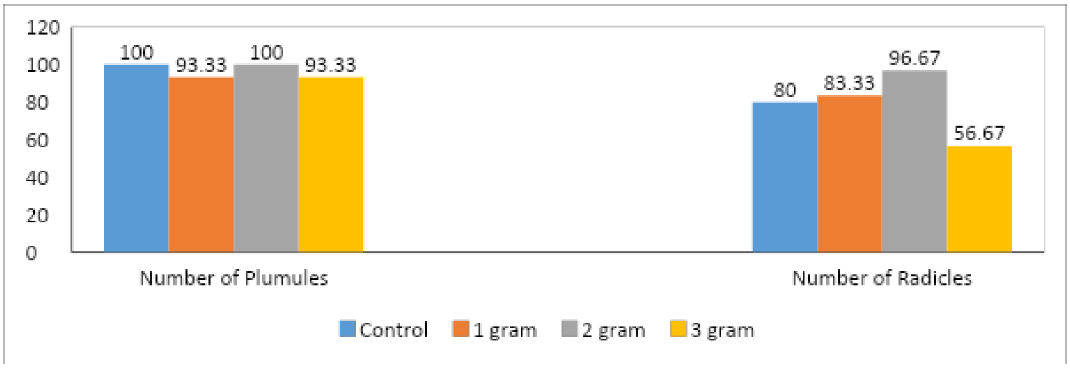
Means in a column with the same letter(s) are not significantly different by Tukey test at ($P\leq0.05$)

Table 2: Ovicidal effect of oil extract from ginger on *Callosobruchus maculatus*

Conc. (ml)	Oviposition	Seeds with eggs	Seeds without eggs	Emergence	Seeds with holes	Seeds without holes
0	1.9667a	2.4000a	3.9333a	1.97a	2.9333a	3.71b
1	2.2667a	2.6333a	3.7000a	1.77a	2.7667a	3.52ab
2	1.5667a	1.9333a	4.1000a	1.57a	2.2000a	3.83a
3	1.3333a	1.8000a	4.2000a	1.27a	2.2333a	3.97a

Means in a column with the same letter(s) are not significantly different by Tukey test at ($P\leq0.05$)

Figure 1: Germination percentage for ginger powder at different concentrations



CONCLUSION

The ginger powder and oil extract in this study have demonstrated potential insecticidal activity against *C. maculatus.* The findings revealed that best concentrations of ginger powder (2g and 3g) and oil extract of 2ml and 3ml, led to highest adult beetle mortality. The number of deposited eggs, on treated seeds were reduced compared to when seeds were left untreated. Thus, these ginger products could be adopted as protectants for stored cowpea seeds. In Nigeria, these plant species are available, inexpensive and edible culinary spices and herbs, thus posing no harmful effects on the environment and life to the consumer.

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EFFECT OF BIOCHAR ON MICROBIAL COLONIZATION AND HEAVY METAL CONCENTRATION IN A POLLUTED SOIL; THE CASE OF AUTOMOBILE WORKSHOP DUMPSITE IN ANYIGBA, KOGI STATE, NIGERIA

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ABSTRACT

A study of the effect of biochar (charcoal) on microbial colonization and heavy metal concentration in polluted soil was conducted for eighth (8) weeks between September to October, during the cropping season of 2018, at the faculty of Agriculture, Kogi State University, Anyigba. The aim of the study was to determine the effect of biochar on microbial colonization and heavy metal concentration in a polluted soil. The experiment was laid out in a completely randomized design (CRD) and the data collected were subjected to ANOVA using SPSS. The study revealed lower count in bacteria and fungi in non-amended polluted soil compared to biochar amended polluted soil which has higher count in both bacteria and fungi. There were significant differences at ($p \leq 0.05$) probability level in both count for bacteria and fungi. The result obtained suggested that the pollution by heavy metals distorted the growth of microorganism and the addition of biochar (charcoal) as an organic amendment helped to increase the number of microorganisms present in the polluted soil. The study also revealed higher concentration of heavy metals in non-amended polluted soil compared to polluted soil amended with biochar which had lower concentration of heavy metals. There were significant differences at ($p \leq 0.05$) in the concentration of heavy metals in the polluted soil at both four (4) and eight (8) weeks. The result suggested the degree of pollution in soil is a function of the concentration of heavy metals in it and that biochar (charcoal) as an organic amendment helped to reduce the concentration of the heavy metals in such polluted soil.

***Key words**: Biochar, microbial colonization, heavy metal, polluted soil.*

INTRODUCTION

Due to several anthropogenic activities, the case of soil pollution has been on the increase. Mining activities, pesticides application, oil spillages, radioactive waste discharge etc, all leads to soil pollution. Dumpsite soils found close to mechanic workshop are used to grow crops. This is because most people believe that the black soil “humus” found in the dumpsite is a rich source of plant nutrient. Dumpsites found around mechanic workshop contain-engine oil, spilled battery contents, petrol, lubricating greases, black coloured soot wastes etc. Thus, there might be presence or accumulation of toxic heavy metals in such soils, which in turn affects microbial diversity (Osu, and Okereke, 2010).

Biochar is a fine-grained, highly porous charcoal substance that is distinguished from other charcoals in its intended use as a soil amendment. Biochar is charcoal that has been produced under conditions that optimize certain characteristics deemed useful in agriculture, such as high surface area per unit of volume and low amounts of residual resins. The particular heat treatment of organic biomass used to produce biochar contributes to its large surface area and its characteristic ability to persist in soils with very little biological decay (Lehmann and Rondon, 2006).

Several researchers (Glaser *et al*., 2002; Lehmann and Rondon, 2006; Warnock *et al*., 2007) reported that compared to other soil amendments, the high surface area and porosity of biochar enable it to adsorb or retain nutrients and water and also provide a habitat for beneficial microorganisms to flourish. Liang *et al*., (2008) posited that by charring the organic material, much of the carbon becomes “fixed” into a more stable form, and when the resulting biochar is applied to soils, the carbon is effectively sequestered. It is estimated that the use of this method to “tie up” carbon has the potential to reduce current global carbon emissions by as much as 10 percent (Woolf *et al*., 2010). Also, biochar has been shown to improve soil qualities (Lehmann *et al*., 2003; *Chan et al*., 2007; *Steiner et al*., 2007; *Major et al*., 2010). The present study is therefore aimed at determining how different loading rates of biochar can help increase the soil microbial population and how this population increase affects heavy metal concentration in a polluted soil.

MATERIALS AND METHODS

Experimental Area

A pot experiment was carried in Faculty of Agriculture, Kogi State University, Anyigba, Kogi State, Nigeria. Anyigba is located on Latitude 7° 15′ - 7°11 29′ N, and Longitude 7° 11′ -7° 32′E, in the southern guinea savannah. The annual rainfall is 1600 mm with mean temperature and average altitude of 25°C and 42 meters above sea level respectively (Amhakhian *et al*., 2010).

Sample Collection

Soil sample was collected from a dumpsite in an automobile workshop close to old Egume road in Anyigba. The surface soil of the dumpsite was cleared to remove large debris such as paper, leather, metals, plastics etc, before samples were collected. Pre-field sample from the collected dumpsite soil was taken to the laboratory to analyze for the concentration lead (Pb), cadmium (Cd) and nickel (Ni) and also to analyze for microbial colony present in the soil before it was used for the experiment.

Soil sample preparation
The soil samples collected from the dumpsite were air dried at room temperature, was pounded to ease sieving and then sieved with a 2 mm sieve of brass to remove debris so as to make it ready for analysis. Soil sample from pots that receive same treatment was collected at the end of the experiment to analyze for both heavy metal concentration and microbial colonization.

Treatment and Experimental Design
The experiment was conducted in plastic pots. Each pot was filled with 5 kg of dumpsite soil from a mechanic workshop in Anyigba. Biochar was applied to the plastic pots at varying rates;
0 tons/hectare (control) = Treatment 1
2 tons/hectare = Treatment 2
4 tons/hectare = Treatment 3
6 tons/hectare = Treatment 4
8 tons/hectare = Treatment 5

Each treatment was replicated five times in a Completely Randomized Design (CRD) to give a total of 25 pots.

Experimental Procedure
Soil samples were collected for both microbial colonization analysis and heavy metal analysis at four (4) weeks and eight (8) weeks after biochar application.

Heavy metal analysis in soil
Heavy metal analysis were determined from solution obtained by first digesting 1g of soil sample with perchloric acid at 550^{O}C and diluting the digest obtained with deionized water, filtered and made up to 50ml in a volumetric flask using deionized water and the heavy metals determined by the (AOAC 2010) Atomic Absorption Spectrophotometer (Varian Company USA).

Estimation of total heterotrophic bacteria (THB) and total fungi content in the soil sample.
Soil samples were collected at four (4) and eight (8) weeks after biochar application. These samples were taken to the Laboratory within 24 hours for the assessment of total heterotrophic bacteria and fungi count.

One (1) gram of soil was collected from each sample to be analyzed and were individually diluted with 9ml of distilled water in ten-fold (serial dilution) until dilution 10^{-7} was obtained. The mls of 10^{-6} and 10^{-7} were inoculated into molten Nutrient Agar (for bacteria) and Saboraud Dextrose Agar (SDA) (for fungi) in Petri-dishes that were appropriately labeled. 10% lactic acid was added to the cooled (50^{o}c) SDA to inhibit bacteria. The inoculated media were allowed to set and plates were thereafter incubated at $35^{o}c$ for 24 hours and plates were inverted before incubation.

Colony forming unit (CFU/ g) on Nutrient Agar were counted after 24 hours, while colony forming unit (CFU/g) on Saboraud Dextrose Agar (SDA) were counted after 72 hours of incubation.

Statistical Analysis

The data generated was subjected to Analysis of Variance (ANOVA). Means were separated using least significant difference (LSD). SPSS was used to analyze statistical data.

RESULTS AND DISCUSSION

MICROBIAL ANALYSIS

Table 1. Microbial count of pre-field soil sample.

Microbes	Total count	Mean count	Cfu/g
Bacteria	145	72.5	7.25×10^{7}
Fungi	230	115	11.5×10^{7}

Table 2. Microbial load (Cfu/g) at four (4) weeks after biochar application.

Treatments	Bacteria total count	Bacteria mean count	Bacteria cell (Cfu/g)	Fungi total count	Fungi mean count	Fungi cell (Cfu/g)
0 ton/ha	191	95.5	9.55×10^{7}	384	192	19.2×10^{7}
2 tons/ha	104	52	5.2×10^{7}	176	88	8.8×10^{7}
4 tons/ha	168	84	8.4×10^{7}	189	94.5	9.45×10^{7}
6 tons/ha	660	330	33×10^{7}	247	123	12.3×10^{7}
8 tons/ha	610	305	30.5×10^{7}	156	78	7.8×10^{7}
LSD			0.540			0.092

Table 3. Microbial load (Cfu/g) at eight weeks after biochar application.

Treatments	Bacteria total count	Bacteria mean count	Bacteria cell (Cfu/g)	Fungi total count	Fungi mean count	Fungi cell (Cfu/g)
0 ton/ha	162	81	8.1×10^{7}	260	130	13.0×10^{7}
2 tons/ha	510	255	25.5×10^{7}	233	117	11.7×10^{7}
4 tons/ha	154	77	7.7×10^{7}	226	113	11.3×10^{7}
6 tons/ha	142	71	7.1×10^{7}	220	110	11.0×10^{7}
8 tons/ha	135	67.5	6.75×10^{7}	287	144	14.4×10^{7}
LSD			0.649			0.373

HEAVY METAL ANALYSIS

Table 4. Heavy metal analysis of pre-field soil sample.

Heavy metals
Lead (Pb)
Cadmium (Cd)
Nickel (Ni)

Table 5. Heavy metal analysis at four (4) after biochar application.

Heavy metals	T1	T2	T3	T4	T5	LSD	WHO standard (1996) mg/kg
Lead (Pb) mg/kg	2.9200	3.1500	2.8800	2.8500	3.1000	NS	85
Cadmium (Cd) mg/kg	0.04200	0.03300	0.02800	0.00500	0.04400	NS	0.8
Nickel (Ni) mg/kg	0.2700	0.3400	0.2800	0.2100	0.3600	NS	35

Table 6. Heavy metal analysis at eight (8) weeks after biochar application.

Heavy metals	T1	T2	T3	T4	T5	LSD	WHO standard (1996) mg/kg
Lead (Pb) mg/kg	1.8100	2.4400	2.3100	1.9000	1.9600	NS	85
Cadmium (Cd) mg/kg	0.03100	0.03900	0.03100	0.02500	0.03900	NS	0.8
Nickel (Ni) mg/kg	0.4200	0.2800	0.3200	0.2400	0.2100	NS	35

NS- not significant

CONCLUSION

In conclusion, this study revealed that the polluted soil contained heavy metals (lead (Pb), Cadmium (Cd) and Nickel (Ni). Also, microorganisms such as bacteria and fungi are also present in the polluted soil- this imply that these microorganisms have been able to develop to become adapted to the polluted soil environment.

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WASTE TO WEALTH: INSIGHTS FROM THE CASSAVA PEEL VALUE CHAIN MANAGEMENT IN SOUTHWESTERN NIGERIA

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ABSTRACT

The Cassava peel value chain can contribute significantly to the bio-economy of Nigeria. However, the cassava peel value chain is weak and there is a paucity of information about the value chain actors. We thus analyzed the profitability of participating in the cassava peel value chain and examined the constraints faced by these actors using descriptive statistics, Semantic differential scale, gross margin analysis, and Ordinary Least Square regression analysis. The study relied on primary data obtained from 438 cassava peel value chain actors randomly selected from three States in Southwestern Nigeria. Our result reveals that the majority of the cassava peel actors are peelers, 183 (41.78%), and local processors, 190 (43.37) who rely mainly on traditional processing methods. The actors realize an average monthly gross margin of ₦54, 641 ($ 54.83). The monthly expenditure. monthly income, education, and household size of actors are the drivers of profitability (P value, 0.05). The instability of cassava prices, inadequate access to credit facilities, and the high cost of hiring labour are the pressing constraints faced by the actors. Efforts should be geared towards the stabilization of cassava prices as well as the provision of credit facilities in other to improve the cassava value chain.

Key words: *Cassava peel, Value chain, Waste, Profitability*

INTRODUCTION

In Africa, cassava (Manihot esculenta) is a tuber crop that is preferred in all nations and cultures (CGIAR, 2018). The vast majority of cassava tubers produced are eaten locally as part of customary diets. Due to its importance in both production and consumption, cassava is an important staple crop. According to FAOStat, Africa produces around 64% (192 million MT) of total global cassava output, with Nigeria being the largest producer with an output of more than 59 million MT, 19.4% of the total production in 2019. In contrast to the 33.8 tons per hectare considered to be the best practice globally, Nigeria's average yield of 8.2 tons per hectare is extremely low (FAO, 2020).

Smallholder farmers who use poor agronomic methods, low-quality inputs, and limited access to automation are the main producers of cassava in Nigeria (Otekunrin & Sawicka, 2019). This has played a significant role in Nigeria's present output of 8.2MT/ha, which is lower than the potential production of 20-30MT/ha with mechanization and proper agronomic practices. The majority of the cassava produced is converted using conventional food processing techniques into regional foods like fufu and gari (FAO & IFAD, 2005; Kreye et al., 2020). The cassava value chain contains significant obstacles that are impeding the crop's potential for generating cash and ensuring food security (Okolie et al., 2018).

The leaves, peels, stems, and starch bagasse are only a few of the waste products generated in the course of processing of cassava (Oghenejoboh, 2015; Oghenejoboh et al., 2017). Typically, these wastes are haphazardly discarded along Nigeria's coast in rivers, unfinished buildings, undeveloped land, and any other open areas, causing significant environmental contamination through the production of effluent (Ogunyinka & Oguntuase, 2020). Before processing, cassava must be peeled, and in Nigeria, large-scale cassava processing produces up to 15 million tons of waste cassava peel each year (Oghenejoboh et al., 2021). As a result, there is a potential to close the nutritional gap through the production of useful products from the waste peel (Oghenejoboh et al., 2016; Okolie et al., 2018). Aside from creating revenue and a means of subsistence, this will help in reducing environmental harm.

Cassava peel has recently gained attention as it is been used as raw material to feed other sectors, particularly the livestock sector (Oparaku et al., 2013; Olukanmi and Olatunji, 2018). Another area of use that has received a lot of scientific attention is the utilization of cassava peels as a feedstock for biogas generation (Aisien and Aisien, 2020; Oghenejoboh et al., 2021). The level of awareness and acceptance among the actors in the cassava peel value chain is quite low, despite the fact that researchers have developed innovative technologies for converting cassava peels into high-quality cassava peel mash as livestock feed (Okike et al., 2021).

To implement evidence-informed interventions, there is a need to understand the current dynamics in the Nigerian cassava peel value chain. However, there is a paucity of sufficient research about cassava peel value chain actors in Nigeria., despite the bioeconomic and livelihood prospects in the cassava peel value chain. This is indeed a challenge that needs to be addressed to fully understand and harness the potential of this valuable resource. Research plays a crucial role in identifying key actors, their roles, challenges, and opportunities within the value chain. In light of the foregoing, we:

a. described the socioeconomic characteristics of the cassava peel value chain actors in southwestern Nigeria;
b. profiled the cassava peel value chain actors based on the type of value addition in southwestern Nigeria;
c. analyzed the profitability along the cassava peel value chain in southwestern Nigeria, and;

d. examined the constraints faced by the cassava peel value actors in southwestern Nigeria

METHODS

The Study Area

This study was carried out in southwestern Nigeria. The South-West is one of Nigeria's six geopolitical zones, and it represents both the geographical and political southwest of the country. They are Ekiti, Lagos, Ogun, Ondo, Osun, and Oyo, six states altogether. The zone is located along the Atlantic coastline, running from the international border with the Benin Republic in the west to the South-South and the North Central in the east. The rainy season (March to November) and the dry season (November to February) in Nigeria both have their own unique weather patterns. The Harmattan dust is a product of the dry season as well; at this time of year, chilly, dry winds from the northern deserts blow towards the southern regions. Worldwide, cassava is grown.

Selection of sample:

The respondents for this study were drawn through a 3 stages sampling technique. In the first stage 3 states namely: Oyo, Ogun, and Ekiti States were randomly selected. Two Local Government Areas (LGAs) were randomly selected in each State at the second stage. Two communities were in turn selected from each LGA, making a total of 12 communities. In the last stage, a total of 438 cassava peel actors were selected through a proportionate sampling method.

Source of data:

This study relies on a primary data set harnessed through a semi-structured interview schedule using the Kobo Toolbox deployed on Android phones. All the respondents were adults and they all gave their consent before we conducted the interview. Participation was strictly voluntary and their responses were treated with utmost confidentiality.

Analytical techniques:

Descriptive Statistics:

The socioeconomic characteristics of the cassava peel value chain actors were analyzed using descriptive statistics such as frequency, percentage, mean and standard deviation all presented in a table.

Gross Margin Analysis:

The profitability of participating in the cassava peel value chain is analyzed using the gross margin analysis. The gross margin is expressed as follows:

GM= TR – TVC

Where,

GM - Gross Margin

TR- Total Revenue

TVC - Total Variable Cost

Ordinary Least Square Regression Analysis:

The drivers of profitability among the cassava peel value chain actors were analyzed using the Ordinary Least Square (OLS) regression analysis. The OLS is explicitly written as follows:

$Y = f(X_1, X_2, X_3, X_4, X_5, X_6, X_7)$

X_1 = Membership of cooperatives

X_2 = Expenditure

X_3 = Monthly income

X_4 = Education in years

X_5 = Age in years

X_6 = Household size

Semantic differential scale:

We examined the constraints faced by cassava value chain actors in the study area using the Semantic differential scale. We chose this rating scale because it enables us to understand the emotional perception that our respondents attempt to convey about the topic of the research in various contexts. These constraints were presented in the treemap chart. The treemap operates as a rectangle-nested visualization. These rectangles are arranged in a hierarchy, or "tree," to represent specific categories within a chosen dimension. In a constrained chart space, quantities and patterns can be compared and displayed. Treemaps show a subset of all relationships.

RESULTS AND DISCUSSIONS

Table 1. Socioeconomic characteristics of the cassava peel value chain actors:

Variable	Category	Frequency (N=438)	Percentage	Mean	Std. Dev.
Gender	Male	101	23.06		
	Female	337	76.94		
Age	<= 30	76	17.35	44.72	13.47
	31-40	112	25.57		
	41-50	118	26.94		
	51-60	83	18.95		
	>60	49	11.19		
HH size	<=5	237	54.11	6.19	4.39
	6-10	159	36.30		
	11-15	27	6.16		
	>15	15	3.42		
Monthly income (₦)	<100,000	354	80.82	100,156.2	301,609.5
	100,001-200,000	46	10.50		

	200,001-300,000	10	2.28		
	300,001-400,000	8	1.83		
	400,001-500,000	5	1.14		
	>500,000	15	3.42		
Monthly expenditure (₦)	<100,000	381	86.99	63,797.05	115,231.9
	100,001-200,000	34	7.76		
	200,001-300,000	7	1.60		
	300,001-400,000	7	1.60		
	400,001-500,000	2	0.46		
	>500,000	7	1.60		
Educational status	Adult education	2	0.46		
	Quranic education	1	0.23		
	Primary education	154	35.16		
	Secondary education	201	45.89		
	Tertiary education	80	18.26		
Membership of coop	Yes	218	49.77		
	No	220	50.23		

Source: field survey, 2023

Table 1 presents an array of the socio-economic characteristics of the cassava peel value chain actors. The cassava peel value chain is dominated by women who constitute 76.94% of the actors. The cassava peel value chain is dominated by young adults with a mean age of 45 years. Their average household size is 6 persons. The value chain actors recorded an average monthly household income of ₦ 100,156.2 and an average monthly household expenditure of ₦ 63,797.05. About half (50.23%) of them had membership in cooperative societies.

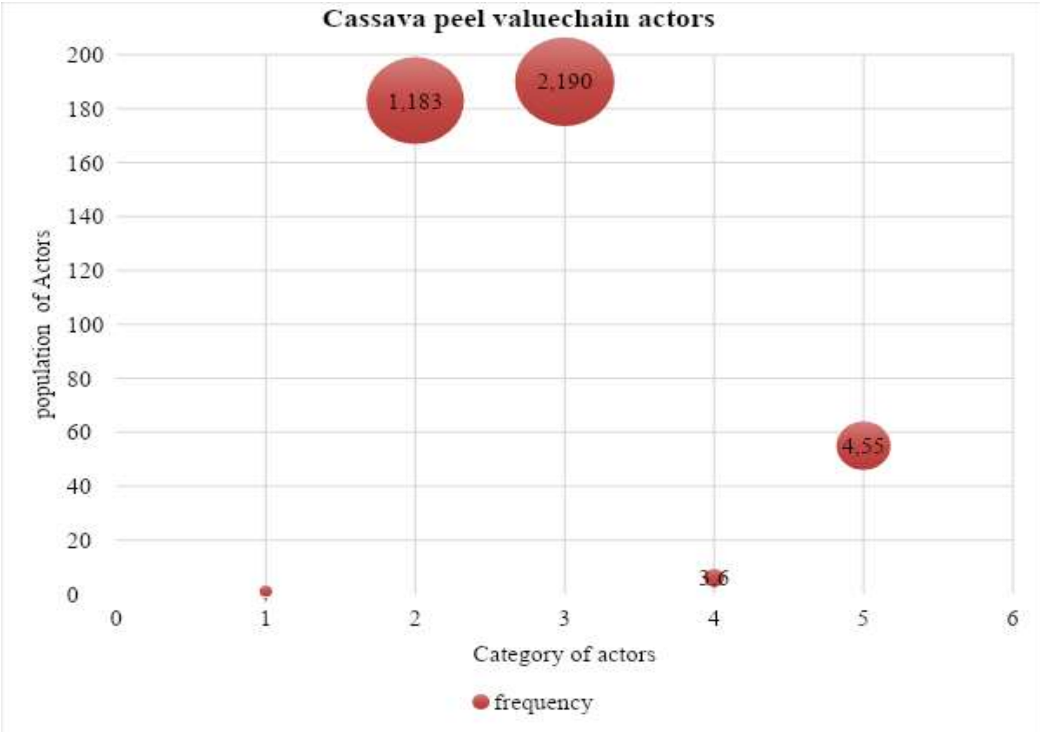

Fig1: Cassava Value chain actors' profile

As shown in figure 1, the majority of the cassava peel actors are peelers, 183 (41.78%), and processors, 190 (43.37) who rely mainly on traditional processing methods of drying, and bagging cassava peels. This finding is in line with that of Egbeocha et al. (2016), who examined cassava peeling machines and discovered that their performance was mostly unacceptable for small-scale processors, who make up the majority of the cassava processing industry in Africa. We found out that 55 of them, constituting (12.55%) were livestock farmers. While 6 (1.36) of them were compost producers, only 1 (0.22%) of them were into biogas production. This suggests that the cassava peel value chain is dominated by local processors using traditional processing techniques. Our findings concur with those of Amole et al. (2019), who claimed that the conventional processing method for cassava peels in Nigeria is sun drying them on the ground.

Profitability of cassava peel management:

Table 2. Gross Margin Analysis

Variables	Amount
Total Revenue (TR) (₦)	70,145.43
Total Variable Cost (TVC) (₦)	15503.79
Gross Margin (TR-TVC) (₦)	54,641.63

% of cassava peel sold	61.23
% of cassava peel used by the household	17.54
% of cassava peel given as a gift	21.23

Source: field survey, 2023

The results in Table 2 show that participating in the cassava peel value chain is a profitable venture with an average monthly gross margin of ₦54, 641 ($ 54.83) monthly by selling an average of 61.23% of the cassava peel they processed. This indicated that participating in cassava peel processing is a profitable venture. 17.54% of the cassava peels were used within the household while the remaining 21.23% of the cassava peels were given out as gifts to neighbours and loved ones who are into livestock production.

Table 3. Determinants of cassava peel actors' profitability

Variables	**Coeff**	**Std. Err**	**T**	**P>|t|**
Membership of cooperatives	-6448.231	473.906	1.44	0.150
Expenditure	-.1903547	.0513256	-3.71	0.000 ***
Monthly income	.1309843	.0188736	6.94	0.000***
Education in years	2279.204	1054.226	2.16	0.031 **
Age in years	115.1799	353.8304	0.33	0.745
Household size	-488.7892	1029.484	-0.47	0.035**
Constant	58674.96	23488.76	2.50	0.013**

Source: field survey, 2023

Number of obs = 412
F (6, 405) = 10.47
Prob > F = 0.0000
R-squared = 0.6343
Adj R-squared = 0.5215
Root MSE = 90057

The value of R-squared in this study indicates that 63% of the gross margin variable was explained by the independent variables. The variables used in the analyses indicate a good fit for the estimated model. Table 3 reveals that monthly expenditure and monthly income (p-value, <0.01) as well as education and household size (P value < 0.05) were the significant determinants of value chain actors' gross margin in the study area. The expenditure of the respondents was identified to be negatively significant which signifies that as the expenditure increases, the gross margin of the household decreases. This is in tandem with apriori expectations. The positive coefficient of the household monthly income denotes an increase in the gross margin as their income rises. More years spent in school also increases the gross margin significantly. However, the size of the household was observed to be negatively significant depicting a decrease in the gross margin as household size increases.

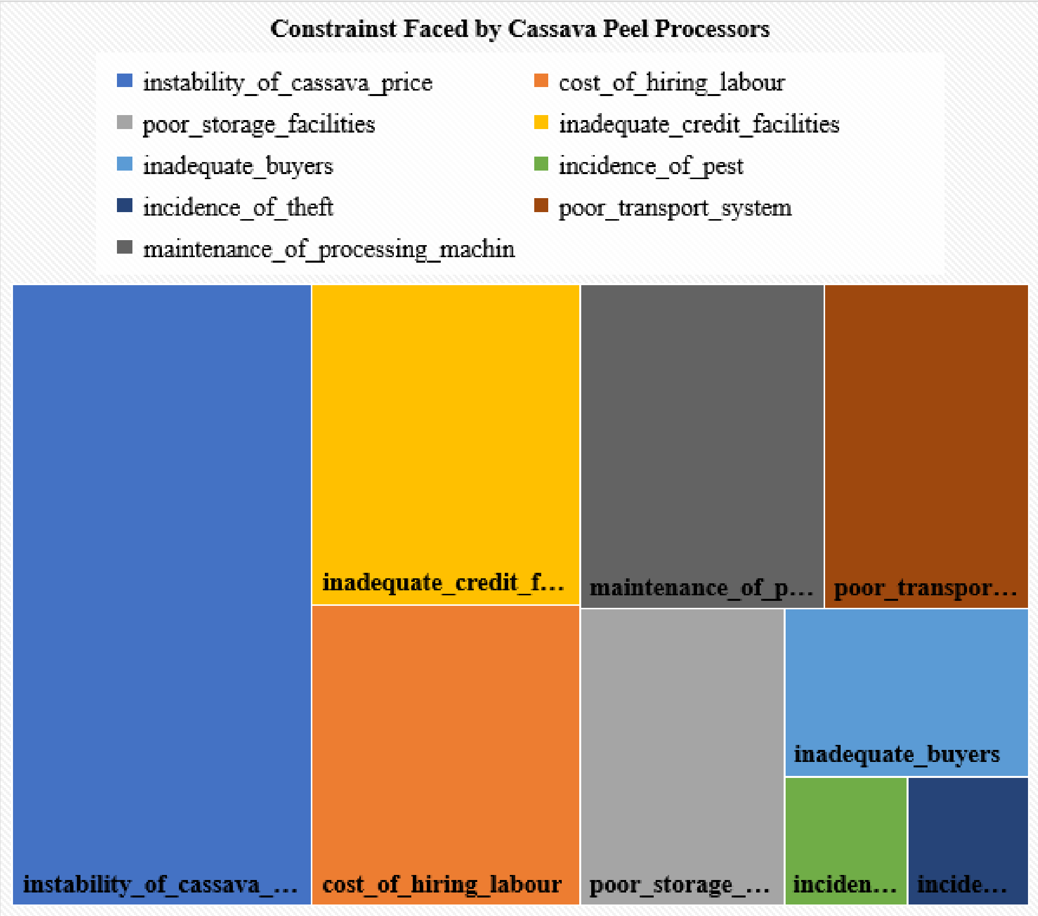

Fig 2: Constraints faced by Cassava peel value chain actors

We looked into the restrictions on actors' actions along the value chain for cassava peels, and the results are shown in the tree map in Figure 2. The price volatility of cassava is the biggest barrier we identified in the value chain. The cassava peel value chain actors were also concerned about inadequate access to credit facilities. The high cost of hiring labour and maintaining processing facilities among actors ranked next on the constraints. Poor transportation and storage facilities were also constraints faced by the value-chain actors. Inadequate buyers, the incidence of pests, and theft were of the least concern among the value chain actors

CONCLUSION

We concluded that the cassava peel value chain is a profitable venture. However, the value chain is weak and dominated by traditional processing methods. Considering the volume of cassava peels produced in Nigeria, strengthening the value chain would help in increasing the income of the value chain actors and repositioning Nigeria's bio-economy and trade. We thus recommend that:

a. policies that would aid the stability of cassava tuber prices in Nigeria should be given the utmost priority
b. efforts should be geared towards provisioning of credit, storage, and processing facilities for the value chain actors as and when due and
c. Stakeholders should also prioritize interventions aimed at educating the cassava value actors.

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UTILIZATION OF CLIMATE SMART AGRICULTURE PRACTICES AMONG RICE FARMERS IN IFO LOCAL GOVERNMENT AREA, OGUN STATE

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ABSTRACT

The study determine the utilization of climate smart Agriculture (CSA) practices among rice farmers in Ifo local government area of Ogun state. Multistage sampling procedure was employed to select the representative rice farmers for the study. With the aid of oral interview and questionnaires, information were elicited from 120 farmers. Data were analyzed using descriptive statistical tools,while inferential analysis were also used to show the level of practices of CSA among rice farmers, The results revealed that majority (80.3%) of rice farmers were male, 67.0% were married, 67.5 % were within economically active age and 85.0% had post primary education. Findings further showed that 85.29% were aware of climate smart agriculture, this helps the farmers in building a sustainable agricultural system that is very resilient to shocks which are related to climate change and other factors posing challenges to agricultural production. High cost of input (mean score = 2.70) , Lack of access to agricultural credit (mean score = 2.64) and Inadequate financial resources (mean score = 2.58) was rated as very major constraint to rice farmers respondents in the area,this implies that majority of the respondent do not have adequate financial resources to adapt CSA practices.It was concluded that Government and private extension organizations should come up with a more robust and inclusive extension programmer that will cover every individual farmer related factor like healthy lifestyle as well as recommended farming practices.

Key words: *Utilization, Climate Smart Agriculture, Rice farmers*

INTRODUCTION

Agriculture remains a fundamental component of Nigerian economy, employing about two-thirds of the nation's workforce. The National Bureau of Statistics (NBS) reported that agricultural sector contributed N41 trillion representing 23.7 percent of the total nominal Gross Domestic Product (GDP) to Nigeria's economy in 2021 (Ripples Nigeria, 2022). Over 70 percent of Nigerians engage in the agriculture sector mainly at a subsistence level (Food and Agriculture Organization (FAO), 2022). The country is rich with abundant human and natural resources, quality soil and favourable climatic conditions for agricultural activities. Nigeria with a population of over 200 million people and a landmass of 923,768 square kilometres has a total of over 79 million hectares of cultivable land (FAO, 2022). A breakdown of the arable land reveals that about 4.6 million hectares are suitable for rice cultivation, of which 1.8 million hectares (39%) is currently utilized for rice production (Demont, 2013). Rice (Oryza sativa) is a staple food for more than 60 percent of the world population (Chikezie, Benchendo, Ibeagwa, et al., 2020). In terms of production, rice is ranked third after wheat and maize at the global level (Akinbile, 2010). It is a leading cereal crop in South East, Asia where it originated and among the widely cultivated food crops (FAO, 2013).

In Nigeria, rice constitutes one of the major crops cultivated with other cereals, root and tubers such as sorghum, millet, cowpea, cassava and yam (Akinbile, 2010). It is a major staple food in the country, and its domestic production has not been able to meet local demand. While land cultivation and production of rice are growing at arithmetic progression, consumption is increasing at geometric progression (Olaolu, Akinnagbe and Agber, 2013). Corroborating this assertion, FAO (2013) observed that the demand and supply gap in rice production is widening annually, thereby resulting in huge import bill for the nation. According to Ammani (2013), Nigeria is the second highest importer of rice and spent over 356 billion naira on the importation of the commodity annually. Nigeria food importation is growing at an alarming and unsustainable rate of 11% yearly, and it has continued to fuel domestic inflation resulting from the use of scarce foreign currency to import rice. Uduma, Adeoye and Agbonlahor (2016) noted that the inability of local supply to meet up with consumers’ demand (consumption) has given rise to the high importation of rice in Nigeria. Uduma et al. further opined that there has been a phenomenal rise in rice importation in Nigeria, estimated at 300 thousand tons annually in recent times which on the average is valued at 300 million naira per annum. They stressed that aside from the huge cost to the Nigerian economy, rice imports expose the country to international market.

The IPCC Fourth Assessment Report projects that climate change could reduce yields by up to 50 percent in some high-risk regions, including sub-Saharan Africa (Elizabeth et al., 2017). According to this report “warming in Sub-Saharan Africa (SSA) is expected to be greater than the global average and rainfall will decline in certain areas. Also, cereal production growth for a range of crops in SSA is projected to decline by a net 3.2 percent in 2050 as a result of climate change”. Climate-Smart Agriculture (CSA) therefore represents a set of strategies that can help combat the above stated challenges of climate change by increasing resilience to weather extremes, adapting to climate change and decreasing agriculture’s greenhouse gas (GHG) emissions that contribute to global warming (Steenwerth et al. 2014). Climate variability and extremes are a major cause of increased food insecurity, with impacts affecting all aspects of food security (FSIN, 2018; FAO, IFAD, UNICEF, WFP & WHO, 2018; Tripathi et al., 2016). Therefore, climate change will not only lead to lower food production and availability, but also lower food quality (Alehile et al., 2022; Tripathi et al., 2016). Smallholder farmers are one of the

most vulnerable groups to climate change and variability. Climate change leads to wearing out of all efforts made by farmers in savings and resources accumulation. Mutabazi and others. (2015) argued that households lacking effective risk prevention are more likely to be more vulnerable.
The knowledge of farmers' current practices and their effect on food production and income generation will give background information to support the utilization of climate smart Agriculture(CSA) practices among rice farmers in Ifo local government area of Ogun state. This study is an attempt to examine such practices with the view of making policy recommendations that will complement farmers' efforts. The objectives of the study are to:

i. describe socio-economic characteristics of the respondents
ii. identify the level of awareness and utilization of climate smart agricultural practices in the study area;
iii. Identify the constraints encountered among rice farmers on CSA.

RESEARCH METHODOLOGY

Description of the study area

The study was carried out in Ifo local government area of ogun state headquarters are in town of Ifo.It is located in the South-Western part of Nigeria.,Its occupies area of 521km^2 and has the Ogun River flowing through its territory.It has a population of 698,837(NPC2006).It lies on the latitude of $6^0$49N^1 and longitudes of $3^0$12E.The main crops abundantly grown in the area are Maize, rice, sugar cane Palm kernel,Kolanut,Banana,Cassava and yam likewise livestocks such as Goats , Poultry and Piggery.

A multi-stage sampling technique was used to select five wards out of the ten wards due to the predominant effect of climate on rice production in the local government, four villages were selected randomly from each ward and this gave rise to twenty villages and then six respondents farmers from each of the four villages making a total of one twenty respondents. Data were collected by means of questionnaire. Descriptive statistics such as percentage, mean scores and standard deviation were used for data analysis,while inferential statistic were also used.

RESULTS AND DISCUSSION

Socio-Economic Characteristics of the Respondents

Result in Table 1 shows the mean age is 48 years implying that there were more economicallyactive people who engage in agricultural activities in the study area. The result shows 80.3% of the respondents were males while 19.7% were female. This shows that majority of the rural farmers were males and this may be attributed to intensive labor requirement of farming activities and their easy access to farmland. Above average of the respondents (67.0%) were married. This implies that greater proportion of farmers in the area were married. The result further indicates the household size of most of the respondents range from 1-5 members (76.7%), while the average household size was 4 persons. A large household increases a household's labor endowment. Also, the result shows that 14.1% of the respondents had no formal education, 85.9% had above primary education. Majority (81.7%) of farmers affirm to have had contact with extension agent in the last 12 months, while the remaining 18.3% have not . Regular contact with extension agents motivates and exposes the farmers to innovations and gives them information on how to use the technologies (Orisakwe and Agomuo, 2011).

Table 4.1:Socio-Economic Characteristics of the Respondents

Variables	Frequency	Percentage	Mean
Sex			
Male	88	80.3	
Female	32	19.7	
Age(years)			
20-30	6	5.0	
31-40	74	67.5	50
41-50	26	18.5	
>50	14	10.0	
Marital status			
Single	18	10.5	
Married	81	67.0	
Widowed	16	10.5	
Divorced	5	2.0	
Educational status			
Primary Education	15	10.0	
Secondary Education	45	40.9	
Tertiary Education	55	45.0	
No Formal Education	5	4.1	
Farming experience in rice(years)			
1-10	97	80.8	
11-20	17	14.2	7
>20	6	5.0	
Household size			
1-5	92	76.7	
6-10	28	23.3	
Annual Income(#)			
50,000-150,000	10	8.3	
151,000-250,000	38	31,7	
251,000-350,000	27	22.5	
>350,000	45	37.5	
Extension Agent			

Yes	95	81.7
No	25	18.3

Sources: Field survey 2023

Climate Smart Agricultural Practices and Utilized by rice Farmers

Table 2 indicates that most respondents with 85.29% were aware of climate smart agriculture. According to Vera et al. (2017) and Teklewold et al., (2013), farmers enjoy more benefits when they adopt multiple strategies, as some of the strategies can be complementary to one another and enable the farmers to exploit relevant synergies. As a result, the adoption of multiple CSA practices helps in building a sustainable agricultural system that is very resilient to shocks which are related to climate change and other factors posing challenges to agricultural production. The result reveal that mixed cropping and mixed farming ranked both ranked 1st. Improved crop varieties ranked 3rd . Cover crop, mulching, intercropping, organic manure, compost making, crop rotation and agro-forestry ranked 4th , 5 th, 6th, 7th, 8th , 9 th , and 10th respectively, while improved fallowing was the least rank in the study area.

Table 2: Climate Smart Agricultural Practices and Utilized by rice Farmers

CSA Practices	Frequency	Percentage	Mean	Rank
Awareness about CSA Practices				
Aware of CSA				
Not Aware of CSA	90	85.29		
	30	14.71		
CSA Practices Utilized				
Improved crop Varieties	118	98.57	2.69	3
Improved fallowing	14	18.57	2.22	11
Compost Making	115	58.27	2.36	8
Agro-Forestry	38	27.34	2.23	10
Mixed farming	120	100.00	2.76	1
Mulching	119	95.00	2.53	5
Crop Rotation	74	52.86	2.26	9
Mixed Cropping	120	100.00	2.76	1
Intercropping	118	87.86	2.52	6
Organic Manure	115	82.14	2.45	7
Cover crops	117	96.43	2.67	4

Sources: Field Survey,2023

Constraint facing practices of CSA by rice farming

The mean score from the constraints confronting the rice farmer production on Climate Smart Agricultural practices in the study area is shown in Table3 below. The result shows that high cost of input (mean score = 2.70) was a very serious problem to rice farmers. Lack of access to agricultural credit (mean score = 2.64) was a major problem. Also, the result shows that high cost of production (mean score =2.59) was also a major constraint. Inadequate financial resources (mean score = 2.58) was rated as very major constraint by respondents in the area. This implies that majority of the respondent do not have adequate financial resources to adapt CSA practices. This corroborates the report by Oyekale (2009), that small-scale farmers, having low resource base, are more vulnerable and less able to cope with the consequences of climate change

Table 4.3: **Constraint facing practices of CSA by rice farming (n=120)**

Constraints	Major	Mild	Not constraint	Mean	Rank
Lack of awareness of CSA practice	66(55.0)	42(35.0)	12(10.0)	2.45	8
Poor extension service on CSA	76(63.3)	39(32.5)	5(4.2)	2.40	11
High cost of input	90(75.0)	24(20.0)	6(5.0)	2.70	1
Limited availability of equipment	87(72.5)	32(26.7)	1(0.8)	2.35	12
Illiteracy of farmers	90(75.0)	30(25.0)	0(0.0)	2.42	10
inadequate financial resource	74(61.7)	42(35.0)	4(3.3)	2.58	4
Poor technical capacity of farmers	44(36.7)	66(55.0)	10(8.3)	2.48	6
Lack of access to agricultural credit	66(55.0)	48(40.0)	6(5.0)	2.64	2
Inadequate government policy	59(49.2)	52(43.3)	9(7.5)	2.45	8
High cost of production	68(56.7)	42(35.0)	10(8.3)	2.59	3
Pest and disease	68(56.7)	40(33.0)	12(10.3)	2.47	7
Lack of improved storage facilities	82(68.3)	33(27.5)	5(4.2)	2.50	5

Sources: Field Survey, 2023

Conclusion and Recommendations

The study established that most of the farmers have appreciable awareness of the climate Smart Agriculture on rice farmers in Ifo Local government area of ogun state. High awareness level. Of climate smart agricultural practices is an advantage on improve in rice production in the study area and were moderately utilized. it is obvious that rice farmers in the study area were mainly small land holders with relatively low efficiency in resources utilization.Lower yields produced by famers in the area may be attributed to lower levels of inputs and less financial stability. Some of the socio-economic characteristics of the rice farmers influencing their level of input utilization and efficiency include age, education, household size, farming experience, land ownership and farm size.

It was therefore recommended that;

i. Agricultural input suppliers should provide farmers with adequate inputs through trusted institutions like friends, Family and extension agents.

ii. Government and private extension organizations should come up with a more robust and inclusive extension programmer that will cover every individual farmer related factor like healthy lifestyle as well as recommended farming practices.

iii. Rice farmers should organize themselves into cooperative organizations to enable them pool resources together to procure modern rice storage and processing facilities.

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CIRCULAR ECONOMY FOR SUSTAINABLE DEVELOPMENT IN AFRICA: ADVANCES AND APPLICATIONS IN FOOD PROCESSING

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ABSTRACT

The concept of a circular economy has gained significant attention as a sustainable approach to resource management and economic development. In Africa, where the challenges of food security, environmental sustainability, and economic development are prominent, the adoption of circular economy principles holds great promise. Existing literature was synthetized after comprehensive search across multiple databases. Qualitative analysis of selected studies was then carried out to identify key themes. This review thus provides some insight on recent advances and applications of circular economy principles in the food processing sector in Africa. It also examines the challenges posed by the linear economy model and highlights the potential of circular economy strategies to address these challenges. Key advances in circular economy practices, including food waste reduction strategies, resource optimization, and circular supply chains, have been found to have positive implications not just for the food processing industry but also for environmental sustainability, economic growth and social well-being. Some barriers to implementing circular economy initiatives in Africa, such as infrastructural constraints, policy challenges, and financial limitations need to be urgently addressed. Collaboration among stakeholders across the food supply chain is essential to drive innovation and implement circular business models effectively within African food industries. Ultimately, harnessing circular economy principles offers a pathway to create more sustainable, resilient, and nutritious food systems for Africa now and in the future.

Key words: *Circular economy, Sustainable development, Food processing, Africa*

INTRODUCTION

In order to ensure that food is available at all times, the transformation of agricultural produce into various forms of food products that are safe and have an extended shelf life is imperative. For many foods that are consumed, some form of processing must be applied to render the food palatable and acceptable. Food processing however comes with several challenges both at the domestic and commercial level. It has been reported that food production accounts for 26% of the global greenhouse gas emissions; more than a quarter of the total emissions produced (Poore and Nemecek, 2018). Waste from processing operations is also produced in varying quantities, and ranges from organic by products to inorganic waste (Chukwu, 2009). This massive production of waste ends up harming the environment. It is a cause for concern and requires mitigation actions.

Agriculture is a significant resource in Africa, accounting for 30-40% of the continent's GDP and employing over 60% of the labor force (Woldemichael *et al*., 2017). The continent hosts a rich diversity of food systems comprising food crops, fruit trees, fisheries, livestock and wildlife. Food processing in Africa therefore continues to grow at a steady rate even though this is limited. According to the Food and Agriculture Organization only 30% of agricultural produce in Africa undergo processing (FAO, 2023). Even though the growth in the food processing sector is advantageous, the challenges that come with food processing and its impact on the environment and climate is unabated.

A major reason why some of the challenges still persist is because Africa's food processing model leans more towards a linear approach with a heavy focus on primary production (FAO, 2017). This approach is characterized by overexploitation of natural resources, loss of biodiversity and is unsustainable. Additionally, there is the prioritization of quantity over quality leading to the production of highly processed but nutritionally deficient foods. Owing to the fact that environmental sustainability is low with this approach, it contributes to food insecurity and economic inequality in the long run.

The concept of circular economy (CE), emphasizes resource efficiency and waste reduction, and is emerging as a promising approach for sustainable food processing. This model offers significant benefits for both economic growth and environmental conservation. The current review aims to explore the application of CE principles in the domestic and commercial food processing sector of Africa as a sustainable alternative to traditional linear approaches.

METHODOLOGY

Existing literature was synthetized after comprehensive search across multiple databases including Google Scholar and Scopus. The literature gathered were screened and selected based on relevance to the topic. Qualitative analysis of selected studies was then carried out to collate findings and elicit trends and key themes.

RESULTS AND DISCUSSION

The concept of circular economy

The utilization of natural resources by humanity has been the cornerstone of civilization in the course of history, shaping economies, cultures and ecosystems. Over the course of time however, humans have adopted a lifestyle such that natural resources are used and disposed of when they are no longer needed with no effort to replace them. This approach to the utilization of resources is termed linear, and is very wasteful. The linear approach to resource utilization is unsustainable because resources are finite. The approach could also be potentially toxic to the environment due to the large amounts of waste produced. This is contrasting to what is observed in natural ecosystems. Natural ecosystems exist such that when resources are used, they are replenished. Animals, for example, may eat plants, and when they die their carcasses decompose to provide nutrients for plants to grow. This interdependence creates a never-ending cycle that is sustained for the long haul. The idea of a circular economy is built on this outlook.

The concept of circular economy, while lacking a definitive singular origin, has historical roots that can be traced back to 1945. Over time, its evolution has been influenced by various schools of thought, each contributing unique perspectives to the concept (Calisto Friant *et al*., 2020). Many authors have different perspectives with regards to its definition. However, since its inception it has been an instrument influencing policy making, value chains, technological, organizational and social innovations. One of the earliest definitions is given by the Ellen MacAuthor Foundation (EMF), who have been promoting the concept of circular economy (CE) since their inception in 2010. They define CE as an industrial system that is restorative or regenerative by intension and design. This replaces the end-of-life concept, employed within the framework of the traditional linear economy model. Geisendorf and Pietrulla, (2018) expand on this definition by emphasizing a systematic approach that is regenerative by design. From the definition of circular economy, it aims to eliminate waste, circulate products at their highest value and regenerate nature.

The circular economy model is intrinsically patterned after the natural cycle, which evidences a perfectly balanced system. There is no such thing as waste. All waste becomes a new source of resource, which, if possible, should add value to a new product (Gardetti, 2019). The system applies principles such that economic growth is not dependent on resource consumption. This ultimately ensures that the environment is not degraded and natural resources are regenerated. Consequently, economic prosperity is fostered side by side with environmental quality (Korhonen *et al*., 2018b). The key principles of circular economy are founded around a 6R frame work: reduce, reuse, refuse, rethink, repair and recycle (Boon and Anuga, 2020).

Some authors have argued that circular economy is a collection of vague and separate ideas from various fields and semi scientific concepts. They assert that the scientific and research content of circular economy is superficial and unorganized. Even though this assertion is debatable, there is no doubt that CE is important for its ability to unify business, community and policy-makers to sustainably work together. Scientific research can thus be recommended to ascertain that the actual environmental impacts of CE toward sustainability (Korhonen *et al*., 2018a).

In order to advance the practice of circular economy some authors have asserted that resilience, creativity, innovation, and transparency are mandatory qualities needed to be present (Gardetti, 2019). Other authors have also asserted that CE related initiatives require integrating bottom-up and top-down approaches to effectively implement and evaluate (Winans *et al*., 2017). Circular economy is a popular notion within policy and business advocacy groups (Korhonen *et al*., 2018b). Government and policy makers are the most important actors responsible when it comes to the implementation of the CE model (Oloyade, 2021).

Circular economy for sustainable development in Africa

Sustainable development is defined by the United Nations (UN) as development that meets the needs of the present without compromising the ability of future generations to meet their own developmental needs, and calls for concerted efforts towards building an inclusive, sustainable and resilient future for people and the planet earth. Even though not legally binding, countries are expected to take ownership and establish suitable frame works to achieve sustainable development (Colglazier, 2015).

The United Nations Development Program (UNDP) reported in 2023 that Africa's progress on the sustainable development goals (SDGs) and the continent's targets of the African Union's (AU) Agenda 2063 has been uneven. Significant differences were found among sub-regions, countries, rural and urban areas. Even though there has been some progress in some areas, the current pace of this progress has been insufficient to achieve the SDGs by the 2030 target (Osman-Elasha *et al*., 2023). Challenges including poverty, inequality, gender disparity, unemployment, health threats, natural disasters and conflicts still persist (Kludza *et al*., 2021). Another report has also said that the progress made by Africa in achieving the SDG's has been very minimal with an average progress score of 53.82% across all African member states in 2020 (UNECA, 2020). There has therefore been a call for strategic acceleration and leveraging opportunities and the circular economy model has been proposed as a suitable alternative developmental approach towards achieving Africa's sustainable development goals (Halog and Anieke, 2021; Nikolaou *et al*., 2021; Oliveira *et al*., 2021; Valverde and Avilés-Palacios, 2021). Some authors have asserted that in the light of current developmental issues, circular economy is a need rather than an alternative (Gardetti, 2019) . Some of the world's largest economies like Japan, Germany, UK, and China have been influenced and sustained by the adoption of the circular economy concept (Winans *et al*., 2017).

Circular economy and sustainability are related concepts, however they both have distinct focuses and objectives. Whereas circular economy aims to avoid resource depletion by creating a closed looped system, sustainability aims to foster utilizing resources in the present such that the needs of future generations are not compromised (Kirchherr *et al*., 2017). This means that circular economy is one of the specific approaches to achieving sustainability. Geissdoerfer *et al*. (2017) identified four key connections between CE and sustainability. First, both concepts involve a systemic shift in economic and production processes. CE further promotes the efficient use of resources, which is a key aspect of sustainable development. CE aims to decouple economic growth from environmental degradation, a core objective of sustainable development. Lastly, circular economy implicitly supports social well-being by fostering equitable opportunities and ensuring the needs of future generations are met without compromising present-day requirements. Circular economy principles are thus relevant to the sustainable development goals. There is a qualitative and positive relationship between implementation of a circular economy system and the achievement of SDGs (Valverde and Avilés-Palacios, 2021).

The concept of circular economy is still developing in Africa (Boon and Anuga, 2020; Desmond and Asamba, 2019; Naidoo *et al*., 2021); and only recently picked momentum between 2018 and 2020 (Naidoo *et al*., 2021). A case study from Kenya and South Africa confirm that the legal and regulatory frame works needed to foster circularity are still in their infancy. Only South Africa is reported to be making some real strides towards the implementation of a circular economy. Rwanda and Nigeria have also taken initial steps as leaders of circular economy implementation (Boon and Anuga, 2020; Naidoo *et al*., 2021).

The implementation of circular economy in Africa has been focused on creating jobs and maximizing the use of resources. Documented studies and evidence of the application of circular economy in more developed countries is available, but little documented evidence exists on African countries. Africa has a lot to learn from emerging economies like India and South America (Desmond and Asamba, 2019).

Circular economy in the African food processing sector

The food processing sector in Africa largely follows a linear model characterized by the taking resources, making and disposing of the final product when it is no longer in use (Boon and Anuga, 2020). An analysis of the circularity of 6 agricultural crops in northern Ghana using the 6R framework, for example, showed the predominance of the linear economy model. It was found that the principles of reuse, refuse, rethink, repair and recycle are not well incorporated into the activities of the agriculture value chain (Boon and Anuga, 2020). With the vital role of transforming raw agricultural products into value-added goods, it is important that sustainability be incorporated into key operations of food processing. The food processing sector in Africa is dominated by nano, micro, small and medium-scale enterprises (NMSMEs); with few multinational food industries (Reardon *et al.*, 2021; Samkange *et al.*, 2021).

There are a number of consequences of the linear approach to food processing in Africa. First, resources tend to be overexploited owing to the fact that fresh raw materials are needed at all times for production. Also, the linear model leads to food loss and waste, environmental degradation and is economically inefficient. Food insecurity also increases because resources are not judiciously utilized. The inefficient processing and transportation methods associated with the linear model of production also leads to the emission of greenhouse gasses (Boon and Anuga, 2020; Halog and Anieke, 2021).With the linear model, production of the food occurs in rural areas, while most consumption occurs in urban areas; and most recyclable organic waste accumulates in uncontrolled dumpsites, sanitation facilities, or is released into the environment (Sekabira *et al*., 2022). The waste produced as a result of food processing could serve as a wealth of resources for producing other products (Tamasiga *et al*., 2022), and there have been success stories in this regard. Liu *et al*. (2023), listed some value-added products that have been produced from converting bioactive compounds in food waste. Nutraceuticals such as resveratrol, monosaccharides, and phenolic compounds have been successfully extracted from food waste such as grape peels produced by wineries, potato peels and banana peels. Food additives such as pectins, biosurfactants, single celled protein and organic fertilizers are all products that have been successfully produced from food waste.

In Africa countries like South Africa, Nigeria, Rwanda and Botswana have taken the lead in the application of circular economy principles in their food processing sector. Maungo Craft Company in Botswana for example, uses left over fruit waste from marula oil production to produce gourmet jams. Waste from marula oil production that would otherwise have been disposed in landfills is repurposed for food and nutrition (Bessa *et al.*, 2021). In Tanzania a start-up company known as Chanzi also sources waste from farms and businesses and converts it into insect feed for fish and poultry using black soldier fly larvae and this generates revenue of up to 3300 USD. This same waste sourced from farms is used to produce fertilizer for plants. A farmer in Uganda is also reported to practice a mixed farming system where waste from pigs is used to grow insects to feed poultry and fish. The pig waste is further broken down and used as fertilizer for green banana plants (Jeffries, 2021).

Challenges and barriers to overcome

There are challenges and barriers to overcome if Africa's food processing sector must transition from a linear economy to a circular economy. One such challenge is the lack of educational programs and public awareness on waste management activities leading to low participation (Boon and Anuga, 2020; Debrah *et al*., 2022). The lack of political will, funding and waste management policies has also been identified as a hindrance. There is also the lack of commitment from policy makers, entrepreneurs and other stake holders to allocate resources for sustainable waste management services (Debrah *et al.*, 2022). Sometimes knowledge of the relevant stake holders is adequate but financial capacity is not.

Beyond policy makers and stakeholders, the food processing sector in itself still utilizes traditional methods of food processing which remain at the empirical level leading to the generation of a lot of waste (Adeyeye, 2017). The upgrade and automation of some food processing methods may help increase efficiency and reduce waste. Some authors have suggested that research should be intensified to improve efficiency in waste treatment, and to minimize waste in food processing and manufacturing operations through advanced manufacturing practices. Despite the establishment of various conversion technologies for food waste at the laboratory scale, the sustainable implementation of these technologies at the commercial level presents challenges and limitations, which require researchers to address these issues in future research (Liu *et al*., 2023).

CONCLUSION

The concept of circular economy holds great promise to contribute to sustainable food processing in Africa. Africa is still in the early stages of transitioning to a more circular economy, but there have been strides made by some African countries. A shift in perspective is necessary, such that waste is no longer seen as a problem that has to be dealt with but rather a rich wealth of resource for sustainable production. For successful implementation of the circular model there is the need for joint participation of stakeholders and policy makers within the African food processing sector.

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MYCOLOGY OF HEAVY METAL RESISTANT MICROBES IN TANNERY AND TEXTILE EFFLUENTS AND ITS ENVIRONS: A CASE STUDY OF CHALLAWA, KANO SATE, NIGERIA

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ABSTRACT

The study was carried out to evaluate fungi species tolerant to heavy metal pollution in the study area which could be considered for bioremediation. Industrial effluents have negatively affected the environment and its inhabitants. Soil, water and effluent (tannery and textile) from Challawa industrial estate, Kumbotso Local Government Area Kano state were sampled to identify fungi species available. Three (3) samples were collected in triplicates each from water, tannery and textile effluents, while ten (10) random soil samples were collected from the irrigated plots. Isolation was carried out using spread plate method and potato destroxe agar (PDA. Isolated fungi colonies in soil samples ranges from 1.1x 10^7-1.8x 10^7 Cfu/gram with a mean of 1.4 x 10 Cfu/gram ^{7}, water samples ranged from 1.0 x 10^7 to 1.6 x 10 Cfu/gram ^{7}with a mean of 1.3 x 10^7 Cfu/gram, tannery effluent samples had a mean of 1.1 x 10^7 Cfu/gram ranging from 8 x 10^6 to 1.3 x 10^7 Cfu/gram, finally textile effluent ranged from 9 x10^6 to 1.5 x 10^7 Cfu/gram with a mean of 1.2 x 10^7 Cfu/gram. Six (6) fungi species where identified in all samples. The identified fungi species in the soil samples were Penicillium marneffe 28.57% (6 of 21), Aspergillus niger and Rhizopus spp 19.05% (4 of 21 each), Malbranchea spp and Candida trapicatis14.26% (3 of 21) each. Three (3) fungi species (Aspergillus niger, Candida trapicatis and Rhizopus spp) were identified in water samples, while five (5) fungi species (Malbranchea spp, Aspergillus niger Penicilium marneffei (Talaromyces marneffei), Aspergillus fumigates and Rhizopus spp) were identified in both tannery and textile effluent. The consistent presence of Penicillium and Aspergillus genera suggests their survival and tolerance level and probably their bioremediation capabilities and this can be ascertained by inoculation into the study area.

INTRODUCTION

For a metal to be considered as a heavy metal it must have a specific density of 5 g/cm^3 which is also termed a hazardous pollutant. Copper, iron manganese, zinc are metals which are essential for the nutrition of life and its processes while metals in the likes of cadmium, nickel and mercury are said to have no physiological use/function to man but instead have been found to cause harmful disorders to man at high concentration (Lenin *et al*., 2014). The ingestion of heavy metals occurs through the inhaling of dust, direct ingestion of the soil, and the consumption of food plants grown in metal contaminated soils (Bigdeli and Seilsepour, 2008) which in turn affects the state of health with diseases such as Minamata disease caused by mercury toxicity from contaminated fish.

Compounds that cause contamination have been grouped into organic and inorganic compounds. Heavy metals are a major component of inorganic contaminants and cannot be degraded. The clean-up of such type of contaminants from environment usually requires their removal. Several conventional technologies have already been used for their removal but most of them are not cost effective and not successful to produce optimum results. Currently, a vast array of biological materials, especially bacteria, algae, yeasts and fungi, have received increasing attention for heavy metal removal and recovery due to their good performance, low cost and large available quantities. (Krishna *et al*., 2017). Recent studies have proved that the strains isolated from the contaminated area have the tendencies to withstand/tolerate toxic conditions. Microbes have been shown to have the capacity to survive by adapting at high concentrations of heavy metals (Anahid *et al*., 2011; Yuan *et al*., 2007). Therefore, there is the need to explore newcomer resistant isolates as eco-friendly alternative means of heavy metal removal from tannery wastewater and other industrial effluents.

Challawa industrial estate is an industrial hub of Kano state where leather and textile tanning takes place. It is eminent that the waste of these industries would have to be disposed either properly or improperly. In most industrial areas in Nigeria, industrial waste/effluent discharge is introduced into the environment either partially treated or untreated. Only about 20% of the large amount of chemicals used during tanning process is said to be absorbed by leather, whereas the rest is released as waste (UNIDO, 2005), which is then discharged into sources of irrigation water, which farmers in turn use for agricultural irrigation. This polluted water contains high amount of toxic chemicals/heavy metals which when taken up by plants are later consumed by man which is very detrimental to man’s health. These heavy metals include mercury, zinc, nickel, chromium, lead, cadmium, arsenic and copper. It has been described by several researchers on the various applications of microorganisms in the remediation of heavy metals with encouraging results (Duruibe *et al*., 2007; Udofia *et al*., 2009; Ademola *et al.,* 2009). But the role of bacteria and fungal isolates has not been adequately explored. It was indicated that there was a positive relationship between levels of metal resistance and bio-accumulation capacity of some fungi (Lakshmanan *et al.,* 2010).

In view of this, the need for a mycological study of heavy metal resistant microbes in tannery effluent discharge site and its environment has been deemed necessary. As it is known that microbes (fungi) present or striving at a polluted site have greater tendencies of withstanding heavy metals and also have bioaccumulation potentials and could be applied for the removal of heavy metals (Lone *et al*., 2008) since these metals are not biodegradable.

In essence, fungi have been found to play a major role in the natural environment in matters of decomposition, transformation and nutrient cycling. The effective understanding of their reactions in high metal concentration conditions may be particularly relevant, in this case, to the detoxification of heavy metal polluted habitats. In recent times Microbes (fungi, bacteria and algae) have been efficaciously used as uptake agents for the elimination of heavy metals from waste streams (Al-Garni *et al*., 2009; Ademola *et al.,* 2009; Wang and Chen, 2009). Over the years studies have been carried out on the tolerance and detoxification of heavy metals by bacterial species but that of fungi is now gaining grounds in many part of the world (Wang and Chen, 2009).Since it has earlier been stated that the microbes present in a contaminated site are those once which have the ten7dencies of withstanding heavy metals and in turn carry out bioaccumulation hence the need to carry out a research on these microbes with fungi in view using Challawa as the study location.

The main objective of this study was to carry out a mycological study to determine the species of heavy metal resistant fungi found in Challawa tannery and textile effluent site and its environs.

MATERIALS AND METHODS

Challawa industrial estate is located in Kumbotso Local Government of Kano sate. Kano state is located in the Northern part of Nigeria covering an area extending between latitude 11^{o}30'N 8^{o}30'E. Challawa River is one of the receiving rivers of tannery effluents from Challawa industrial estate (see Figure 1). The industries in the Challawa industrial estate range from tanneries and textile to foods and packaging industries. The effluents from the industries in the estate were connected by a canal and channelled directly in to River Challawa. The climate of the area is dominated by the cyclical migration inter tropical convergence zone. The marked season of climate, the dry season is longer than wet, with highest rainfall in July and August (Kabiru, 2007).

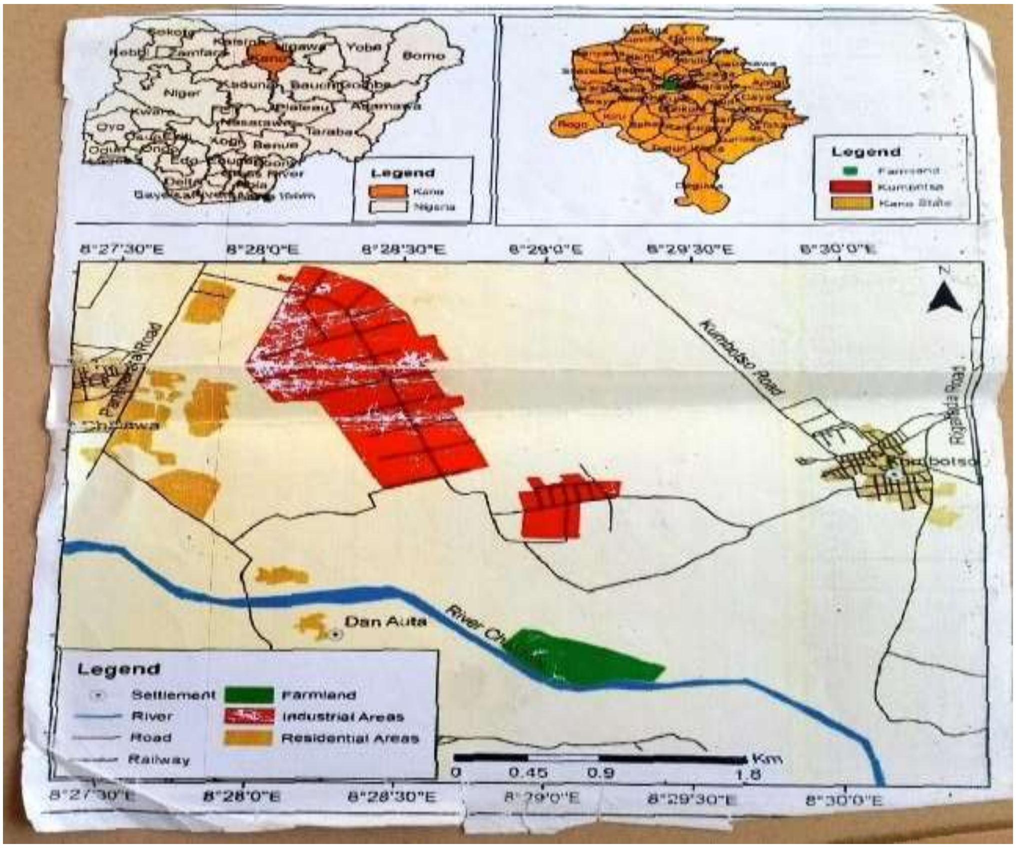

Figure 1. Map showing the showing the location of Kombotso Local and the Challawa industrial estate.

Soil samples were collected from Challawa farm lands located in Kumbotso Local Government of Kano state, where tannery effluent contaminated water is used for irrigation purpose. This soil is exposed to different pollutants including heavy metals. Therefore, it is expected that microorganisms isolated from such polluted soil is well adapted and tolerated to such environmental stress.

The soil samples were collected with a spade into plastic bags cleaned with cotton soaked in about 70% alcohol (Reza and Singh 2010). Soil samples were taken randomly across irrigated farmlands in the study area, after which it was transported to the laboratory where the soil samples were tested. The wet soils were allowed to air dry by spreading on a sheet of paper away from contamination or external particles. The samples were turned/ mixed frequently to expose fresh surface to dryness. The samples were grinded softly so as to reduce the clustering of the soil both in a tender way to avoid breakage of the particles using a piston and a mortar then sieved with a 2mm mesh sieve and the coarse particles discarded. The powdered form was stored for subsequent analysis.

Water samples were collected from designated sample collection points (in triplicates) across the length of the river. Three (3) sampling points were noted these including the Upstream (Ups), Point of effluent discharge into the water (Pd) and the Downstream (Dst).Effluent samples were also taken in triplicates from three designated points along the waste channel. The first sampling point was the point of effluent discharge from the industries into the waste channel (Sample 1). The second sample was gotten some 400 metres away from Sample 1 (Sample 2) while the third sample was gotten another 400 metres away from Sample 2 (Sample 3). Water and effluent samples were obtained by dipping sterile bottle 25cm below water surface and effluent against the flow of water.

After soil, water and effluent samples were collected; they were taken to the laboratory within 24 hours for the assessment of total heterotrophic fungi count and identification.

The method of Srivastava and Thakur, (2006) was used. The soil samples were serially diluted into 10 folds and appropriate diluted samples (0.1 ml) were inoculated on the potato dextrose agar (PDA) plate. The plates were incubated at $30^{o}C$ for four days. The fungal colonies on the PDA plates were counted, isolated, purified and stored on PDA slants for further studies. Fungi count was achieved using this equation:

F_o = Number of colony formed x dilution factor / Volume of inoculum used …. Eqn. 1
Where: F_o = Fungi count

Dilution factor 10^4 was used in this study. In soil, fungi count were measured in coliform forming unit per gram of soil (Cfu/g) while in water, coliform forming unit per millilitres (Cfu/ml) was used.

To identify isolated fungi, 2-3 drops of lactose phenol cotton blue was placed at the center of a clean glass slide. Isolated fungi were then introduced to make a smear on the slide with lactose phenol cotton blue which was covered with a glass cover slip. The smear was mounted on the slide of the microscope for observation. Fungal colonies were distinguished based on their cultural characteristics such as colour, texture, and diameter of the colonies, and microscopic characteristics of the isolates using a taxonomic atlas. Important identification criteria such as macro-morphology (Colony color, Colony size), micro morphological Criteria (conidiophores and conidia) whether columnar or radiate or conidial heads: uni or biseriate, Ascomata and Ascospores, were used to identify the fungi (Davise, 1939).

Data obtained from this study were subjected to descriptive statistics. Means and Ranges were used to describe the results.

RESULTS AND DISCUSSION

In regards to this study, fungal species which belonged to five (5) different genera where identified from ten (10) sampled farms in Challawa industrial zone (Table 1). The genus

Penicillium (a parasitic fungi), was the most dominant, which was observed in 6 out of 10 plots sampled constituting 28.57% (6 of 21) of the total fungi identified, denoting highest survival and competitive abilities. In the genus, one species (*Penicillium marneffei)* was identified. Next were *Aspergillus* (which is a mould fungus) and Rhizopus (saprophytic fungus) with each accounting for 19.05% (4 of 21 each) of the fungi identified with these genera having single species (*Aspergillus niger* and *Rhizopus spp).* And finally *Malbranchea* and *Candida* both accounted for 14.26% (3 of 21 each) of the total fungi identified, with *Malbranchea spp a*nd *Candida trapicatis* their species; an observation indicating the very low suitability of such environment for their survival. These species are decomposers and moulds respectively. Arnold and Kaputska (1987) reported that different soil fungal species can exhibit different degrees of pollution tolerance and many species could be reduced or completely eliminated in polluted soil (Gildon and Tinker, 1981). From the result gotten in the study area, it is safe to say fungal species that showed tolerance to heavy metal pollution are basically moulds and decomposers.

Table 1. Fungi Microscopy (Soil)

Sample	Fungi identified
Plot 1	*Candida trapicatis, Aspergillus niger*
Plot 2	*Aspergillus niger, Penicillium marneffei, Rhizopus spp*
Plot 3	*Aspergillus niger, Candida trapicatis*
Plot 4	*Malbranchea spp, Candida trapicatis*
Plot 5	*Rhozopus spp, Malbranchea spp*
Plot 6	*Penicillium marneffei, Rhizopus spp*
Plot 7	*Penicillium marneffei, Aspergillus niger*
Plot 8	*Penicillium marneffei, Malbranchea spp*
Plot 9	*Penicillium marneffei*
Plot 10	*Rhizopus spp, Penicillium marneffei*

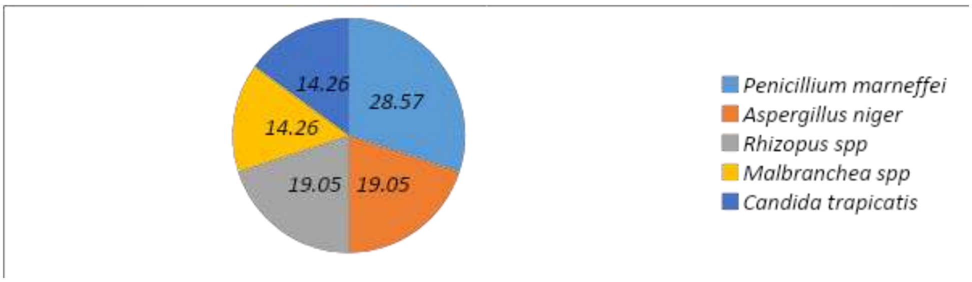

Figure 1. Fungi Microscopy (Soil)

Only three (3) fungi species were identified, *Aspergillus niger* (Ups, and Dst), *Candida trapicatis* (Dst and Pd) *and Rhizopus spp* (Dst). The presence of *Aspergillus niger* (identified at Ups, and Dst),shows its ability to strive in areas with or without pollution.

The identification of *Candida trapicatis* both Ds and Pd samples shows its ability to tolerate heavy metal pollution. In view of this, this species can be exploited in the removal of heavy metals from polluted waste lands. (Glazer and Nikaido, 1995). *Rhizopus spp* which was identified in the Ups shows its either weak tolerance ability or inability to tolerate heavy metal polluted environment, owning to the fact that it was totally absent in Pd and Ds.

Table 2. Fungi Microscopy (Water)

Sample	Fungi identified
Dst	*Aspergillus niger, Candida trapicatis*
Pd	*Candida trapicatis*
Ups	*Rhizopus spp, Aspergillus niger*

Dst = Downstream, Ups=upstream, Pd= Point of effluent discharge into water

Table 3. Fungi Microscopy (Tannery Effluent)

Sample	Fungi Identified
Sample 1	*Malbranchea spp, Aspergillus niger*
Sample 2	*Penicilium marneffei (Talaromyces marneffei), Aspergillus fumigatus*
Sample 3	

Table 4. Fungi Microscopy (Textile Effluent)

Sample	Fungi Identified
Sample 1	*Rhizopus spp, Penicillium marneffei, Aspergillus niger*
Sample 2	*Rhizopus spp, Candida trapicatis*
Sample 3	*Aspergillus fumigatus, Rhizopus spp*

For the identification of Fungi five (5) different genera where identified in both tannery and textile effluent which are *Candida, Rhizopus, Aspergillus, Malbranchea and Penicilium (Talaromyces)*. In the tannery effluent these species of above mentioned genera were identified *Malbranchea spp, Aspergillus niger, Penicilium marneffei (Talaromyces marneffei),* and *Aspergillus fumigates.* Also for textile effluent sample these species were identified; *Rhizopus spp, Penicillium marneffei (Talaromyces marneffei), Aspergillus niger, Candida trapicatis,* and *Aspergillus fumigates.* The consistent appearance of these species *Aspergillus niger* and *fumigates* of the genus Aspergillus, and *Penicilium marneffei* in both tannery and effluent samples proves their ability to survive heavy metal pollutionas several reports have shown that organisms in tannery effluent utilize phenols and other hydrocarbons as source of energy (Mythili and Karthikeyan, 2011).

The fungi count analysed for the soil sample ranged from $1.1x\ 10^7$-$1.8x\ 10^7$ with a mean of $1.4\ x\ 10^7$ (Table 5). The variations observed in the number of colony count could be due to the homogeneity (differences in structure, texture, colour and biomass).

Table 5. Fungi Count for Soil Sample

Sample	No of colony counted	Dilution factor (df)	Volume of inoculums (ml)	Cfu/gram
Plot 1	11	10^4	0.1	1.1×10^7
Plot 2	13	10^4	0.1	1.3×10^7
Plot 3	15	10^4	0.1	1.5×10^7
Plot 4	14	10^4	0.1	1.4×10^7
Plot 5	17	10^4	0.1	1.7×10^7
Plot 6	12	10^4	0.1	1.2×10^7
Plot 7	16	10^4	0.1	1.6×10^7
Plot 8	13	10^4	0.1	1.3×10^7
Plot 9	18	10^4	0.1	1.8×10^7
Plot 10	15	10^4	0.1	1.5×10^7

After the analysis for the fungi count in the water samples, it was noted that the mean number of fungi colonies was 1.3×10^7 (Table 6) and the Cfu/ml ranged from 1.0×10^7 to 1.6×10^7. It was observed that the fungi colony count for water sample was at its lowest at the upstream (1.0×10^7) that is before the point of effluent discharge, highest at point of effluent discharge or interception (1.6×10^7) with a drop to 1.4×10^7 at the downstream, may be indicative of the fact that these fungi species possess metabolic pathways to accumulate heavy metals in their cells.

Table 6. Fungi Count Water Sample

Sample	No of colony	Dilution factor	Volume of inoculums (ml)	Cfu/ml
Dst	14	10^4	0.1	1.4×10^7
Pd	16	10^4	0.1	1.6×10^7
Ups	10	10^4	0.1	1.0×10^7

Where: Dst = Downstream, Ups =upstream, Pd = Point of effluent discharge into water

In the fungi count for water sample the mean number of fungi colony was 1.1×10^7 ranging from 8×10^6 to 1.3×10^7.

Table 7. Fungi Count for Tannery Effluent Sample

Sample	No of colony	Dilution factor	Volume of inoculums (ml)	Cfu/ml
Sample 1	11	10^4	0.1	1.1×10^7
Sample 2	8	10^4	0.1	8×10^7
Sample 3	13	10^4	0.1	1.3×10^7

For textile effluent the mean of identified fungi colony was 1.2×10^7, with Cfu/ml ranging from 9×10^6 to 1.5×10^7.

Table 8. Fungi Count for Textile Effluent Sample

Sample	No of colony	Diluents factor	Volume of inoculums (ml)	Cfu/ml
Sample 1	12	10^4	0.1	$1.2 \, x \, 10^7$
Sample 2	15	10^4	0.1	$1.5 \, x \, 10^7$
Sample 3	9	10^4	0.1	$9 \, x10^7$

The fungi colonies identified in the tannery effluent sample is lower than those identified in all water samples (upstream, downstream and at point of effluent discharge). This could be due to the high level of toxicity of these pollutants.

CONCLUSION

The study was also able to reveal a striving fungi habitat of several species indicative of the fact that these identified fungi species are well adapted, can tolerate, or possess ability to accumulate heavy metals in their cells.

The consistent presence of the genera *Penicillium* and *Aspergillus* in must soil plot samples proves their abilities to tolerate heavy metals which in turn suggest heavy metals remediation abilities. The genus *Aspergillus* was must identified in both the tannery and textile effluents which indicates its survival and remediation abilities.

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EFFECTS OF ENVIRONMENTAL FACTORS ON YIELD OF RICE (ORYZA SATIVA) FARMERS IN IKWO LOCAL GOVERNMENT OF EBONYI STATE, NIGERIA

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ABSTRACT

The study assessed the effects of environmental factors (climate change, land degradation, deforestation etc.) on rice yield among farmers in Ikwo, Ebonyi State. Using multistage sampling techniques, 80 farm units were selected, and structured questionnaires were employed to gather data. Analysis encompassed descriptive and inferential statistics, including frequency distributions, percentages, mean, likert scale, total factor productivity (TFP) model, and multiple regression. Results revealed that a majority (67%) of respondents were aged between 46-65 years, with an average age of 49 years. Education-wise, 38% had secondary education, 30% had primary education, and 20% had no formal education. Household size analysis indicated that 60% had above 10 persons, while 38% had 6 to 10 persons. Environmental factors affecting rice yield included soil fertility, temperature, precipitation, humidity, pests and diseases, mulching, afforestation, deforestation, agroforestry, land management, and organic manure. Soil fertility and temperature were identified as major factors affecting rice yield by 92.25% of respondents. TFP analysis revealed a total output of ₦90,930,000 and total input use of ₦25,313,998, with a TFP of 3.59. Multiple regression analysis showed significant effects of environmental factors on rice yield (F-value = 2.16, P-value = 0.0194, R^2 = 0.3209). It is clear these environmental factors affect rice yield, therefore government agencies and partners saddled with responsibility of combating environmental issues should help these farmers implement or internalize more effective and sustainable practices especially in the area of technology, sustainable production practices because they are poor resource based and their choices are limited in terms of increasing rice yield.

INTRODUCTION

Rice is a significant crop globally; accounting for 25% of all cereal production and being the most commonly consumed cereal by humans (FAO, 2021; Vinci *et al*., 2023). In Nigeria, rice is a staple food, and its production plays a crucial role in ensuring food security across the nation (FAO, 2021). As rice production increases, it has a positive impact on income generation, job creation, and poverty reduction, particularly in rural areas where agriculture is a primary livelihood (Adebayo, 2020). Ebonyi State is known for its agricultural prowess, with rice being one of its essential crops due to the state's favorable climate and fertile soil (Ihuoma *et al*., 2020). However, environmental factors such as climate change, rainfall, temperature, humidity, soil fertility, and pest infestation greatly affect rice production (Idu *et al*., 2023; Sufiyan *et al*., 2020; Chiraini, 2022). Climate change has especially negative effects on rice production, leading to decreased crop yield and grain quality, flood destruction of farmland, a high incidence of weeds, pests, and diseases, and a decrease in soil fertility (Idu *et al*., 2023; FAO, 2021; Vinci *et al*., 2023). Despite the importance of rice production in Ebonyi State, there is limited research on the implications of these environmental factors on rice yield. Therefore, this study aims to investigate the implication of environmental factors on rice yield of farmers in Ebonyi State.

METHODOLOGY

Total factor productivity

The productivity of rice productivity was estimated using the Total Factor productivity (TFP) model as was used y Coelli and Battese in 1996 and adopted by Osanyinlusi and Adenegan, (2016).

FP = Total Output.Total input (3.1)

TFP = output/input (Naira)

Multiple Regression Model

In order to examine the effect of environmental factors on rice yield, a multiple regression analysis was used. The dependent variable is the rice yield and the independent variables are environmental factors. The multiple regression model was explicitly specified as:

$$Y = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \beta_6X_6 + \beta_7X_7 + \beta_8X_8 + e \quad (3.2)$$

Where,

Y = Rice yield (Kg/Ha)

x1= Climate change (1=yes; 0=otherwise)

x2 = Deforestation (hectares/number of tree fallen)

x3 = Afforestation (hectares/number of trees planted)

x4= Soil fertility (1=high; 0=low)

x5 = Agro-forestry practice (1=yes; 0=no)

x6= Land management (number of land management practices e.g irrigation)

x7 = Mulching (no unit)

x8 =Organic manure (quantity of organic manure use in kg)

x9 = Pest and disease infestation (1=yes; 0=no)

β_0 = is the intercept

β_1-β_n = coefficients to be estimated

e = stochastic error term

RESULTS AND DISCUSSION

Socio-economic Characteristics of Respondents

Socio-economic characteristics of the respondents were presented in the table below. The average age of the farmers were about 49 years, with the majority of them, having an age ranges of 46 to 55 years. The result shows an aging farming population, and indicates youth aversion to agriculture, as only farmers with dwindling energy are left to cultivate land. This has severe implications for agricultural production and productivity as younger farmers have greater capacity to adopt innovations compared to older farmers (obi *et al* 2023). These findings agree with the study of (Nwaru *et al* 2010) that the respondents were a bit old with the average age of about 52 years for smallholder food farmers in southern Nigeria.

The result showed that 48 % of the samples respondents were married. About 19 % were single while 2.5 % were divorced and 18 % were widowed. As such, marriage confers special privileged on households to access lands in the community, which will help in meeting the needs of their families. This is consistent with obi et al 2019 and Ozor *et al* (2015) that majority of the respondents in the study area were married. 100 % of the respondents agreed they had contacts with extension personnel and services between 1-5 times in the cropping season. The average number of extension contacts was about 4 times. It is established in literature that the more number of extension contacts farmers have, the better awareness on environmental factors that affect their rice yield.

The result showed that 20 % of the respondents had no formal education, while about 80 % of them had formal education. Out of the 80 %, about 30 % only attended primary schools, 38 % attended secondary school while 12% attended tertiary institutions at various levels. The average year of schooling of the respondents was 8 years (table 1). This shows that the farmers had a very low level of formal education as majority of them barely completed primary education, with a handful of others attempting secondary education. This has severe implications for their ability to access and utilize new and improved techniques and innovations in agriculture. This is consistent with the results of obi *et al* (2021) and Otitoju (2016) that respondents had a very low level of formal education for smallholder food farmers in Ebonyi and Imo States. The majority of the respondents (60 %) fell within the household size of above 10, followed by 38 % of them which fell within the range of 6-10 persons and only about 2 % fell within 1-5 persons per households. The result shows that the average household size was 10 persons.

Majority (89 %) of the respondents belonged to cooperative society while 11 % declared no membership of any cooperative society. It is expected that social participation could enhance farmer’s awareness of environmental factors that affect their yield and adapt result-oriented coping strategies.

Table 1: Frequency Distribution of the Respondents by their Socio-economic Characteristics

Personal characteristics	Frequency	Percentage (%)	Mean
Gender			
Male	45	56.25	
Female	35	43.75	
Age			49
36-45	12	15.00	
46-55	49	61.25	
56-65	12	15.00	
66-75	7	8.75	
Marital status			
Married	48	60.00	
Single	15	18.75	
Divorced	2	2.50	
Widow	10	12.50	
Widower	5	6.25	
Extension contacts (years)			
1-5	80	100	
Qualification			
No formal education	16	20.00	
Primary school	24	30.00	
Secondary school	30	37.50	
NCE/OND	7	8.75	
HND/Tertiary	3	3.75	
Average year of education			8
Household size			10
1-5	2	2.50	
6-10	30	37.50	
Above 10	48	60.00	
Membership of corporative			
Yes	71	88.75	
No	9	11.25	

Field work, 2023.

Types of Environmental Factors Affecting Rice Yield

This section deals with environmental factors affecting rice yields. A number of environmental factors were identified by the respondents in the study area. These were soil fertility; temperature; precipitation; humidity; pest and diseases, mulching; afforestation; deforestation; agroforestry; land managements and organic manure. About 96.25 % of the respondents identified soil fertility and temperature as the major environmental factors they face in the area while 88.75 % and 87.50 % identified precipitation and humidity as the environmental factors affecting rice yield respectively.

Pest and diseases and mulching were shown by about 91.25 % and 61.25 % of the respondents as environmental factors that affect yield. Afforestation and agroforestry were shown by 83.75 % and 82.50 % of the respondents as environmental factors that affect yield while 91.3 % identified deforestation as the environmental factor that affect rice yield. Lastly, 96.25% of the respondents indicated organic manure as the environmental factor which affect rice yield in the area. Enete *et al* (2015) reported that incidence of pests and diseases was a major factor to increased agricultural productivity if farmers in Nigeria. Most of the time, the farmers are not well equipped to tackle these menace, either due to ignorance or lack of access to appropriate pesticides and insecticides, This results in fluctuation of agricultural yield and productivity.

Determination of the productivity level of rice farmers

The productivity level of rice farmers in the study area is presented in table 3. The result reveals the cost of farm inputs incurred from the cost of production was ₦25,313,998 which includes costs from: Land (hectares) (₦1213100); Labour (number) (₦3,002,000); Herbicides (litre) (₦229618); pesticides (litre) (₦121,330); seeds/seedlings (kgs) (₦1,374,200); water (litre) (₦74,300); weeding (number) (₦2,228,700)); Transportation (naira) (₦298,950); Fertilizer (kgs) (₦4,439,200)

Table 2: Types of environmental factors affecting rice yield

Variables	Frequency	Percentage (%)
soil fertility	77	96.25
Temperature	77	96.25
Precipitation	71	88.75
Humidity	70	87.50
Pest and diseases	73	91.25
Mulching	49	61.25
Afforestation	67	83.75
Deforestation	73	91.25
Agroforestry	66	82.50
land management	76	95.00
Organic manure	77	96.25

***Multiple responses Source:** field survey, 2023.

Table 3: Determination of the productivity level of rice farmers

Farm inputs	Quantity in Kg/litre/ha/no	Cost (₦)
Land	12	12131000
Labour	1862	3002000
Herbicides	601	229618
Pesticides	324	121330
Seeds/seed/seedlings	459	1374200
Organic manure	1582	1414700

Water	0	74300
Weeding	1334	2228700
Transportation	0	298950
Fertilizer	8038	4439200
Total input cost		25,313,998

Source: 2023 field survey

Total Factor Productivity of the rice farming in the study area
TFP = Total Output Total input
TFP = output/input (Naira)
Total output = ₦90,930,000
Total input = ₦25,313,998
TFP = ₦90,930,000₦25,313,998
TFP = 3.59

Furthermore, the study reveals the total output of ₦90,930,000 from the quantity of rice produced and sold by rice farmers in the study area. The total productivity factor analysis was shown as 3.59. The result shoed that the total factor productivity of rice farmers in the study area is greater than one which implies a positive trend in the efficiency with which inputs and other resources were transformed to rice output The study of Oyita and Otuisi (2023) examined the effects of total factor productivity on rice output in Nigeria. The result showed that although there is a positive trend in rice total factor productivity in Nigeria, over the years, the average total productivity factor is regressive that is less than one.

Multiple regression of environmental factors on rice farming yield
Table 4 presents the regression estimate of the effects of environmental factors (rainfall, precipitation, temperature, humidity, soil type, pest and disease attacks, weeds, flood, deforestation, afforestation, agroforestry, mulching, land management and soil fertility) on rice yield. It was determined by the multiple regression model form taking into cognizance its number of significant variables, F-value (2.16), P-value (0.0194), and $R^{2.}$ (0.3209). The R^2 value of 0.3209 indicated that 32.1% of the total variations of the endogenous variables were fully explained by the environmental variables observed. The F-value implies the significant level at 5% which suggest that there was significant relation between environmental factors and rice yield. Therefore, the hypotheses should be rejected. Soil type was positively significant at p-value of 5% level. This implies that soil type affects rice yield. The result of the analysis also showed that temperature, soil type, weeds, flood, deforestation, rainfall, and land management were negatively significant at 10% level of significance while precipitation, humidity, pest and disease attacks, afforestation, agroforestry, mulching, and soil fertility were all positive at 10% level of significance.

Table 4: Multiple regression of environmental factors on rice farming productivity.

Variables	Coef.	St.Err	value	Sig.
rainfall	134.912	150.4864	0.373	*
precipitation	93.49492	152.6555	0.542	*
temperature	-118.6639	107.1268	0.272	*
humidity	471.2076	130.5264	0.001	***
soil type	-14.3519	110.4773	0.897	*
pest and diseases	131.7935	104.7411	0.213	*
weeds	-136.2044	103.9621	0.195	*
flood	-73.75269	92.90473	0.430	*
deforestation	-4.623102	80.71347	0.955	*
afforestation	35.38952	110.2442	0.749	*
agroforestry	88.57322	102.9391	0.393	*
mulching	70.26714	94.17403	0.458	*
land management	-.1438509	87.01255	0.999	*
soil fertility	28.52099	76.10651	0.709	*
constant	-1036.41	1388.083	0.458	*
Adjusted r-squared	0.1723	Number of obs	80	
R-squared	0.3209	Prob> chi2	0.0194	

*** denotes P ≤ 0.01, ** denotes 0.01 <P≤0.05, while*0.05<P≤0.10

Source: Field Survey 2023.

CONCLUSION

It is clear these environmental factors affect rice yield, therefore government agencies and partners saddled with responsibility of combating environmental issues should help these farmers implement or internalize more effective and sustainable practices especially in the area of technology, sustainable production practices because they are poor resource based and their choices are limited in terms of increasing rice yield.

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VERMICOMPOSTING AS AN EFFECTIVE APPROACH TO VALORIZE MUNICIPAL SEWAGE SLUDGE AND MANAGEMENT OF BIO-SOLID WASTES

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ABSTRACT

Developing countries are facing significant challenges in managing municipal solid wastes and bio-waste. Municipal sewage sludge end-use practices in these countries pose environmental concerns and are generally unsustainable. In Sub-Saharan Africa, the volume of waste generated is projected to reach 269 million tonnes by 2030. Unfortunately, most of this waste is not adequately managed or collected, leading to adverse environmental effects. Urban areas are particularly affected, with large waste piles blocking open drainages and causing water-borne diseases such as Cholera and Typhoid. Improper management of solid waste and bio-waste is often due to a lack of political will, inadequate funding, limited collection coverage, and insufficient environmental education and awareness. To address these challenges, recycling municipal solid waste and bio-waste into useful resources is a promising solution for sustainable waste management. This research investigated the potential of using earthworms to compost municipal sewage sludge along with other biowaste for agricultural purposes. A 50-day pilot experiment was conducted to process the sewage sludge blended with other bio-waste (coffee husks, and cow dung) using *Eisenia fetida* earthworms. After 50 days of vermicomposting at ambient greenhouse temperatures, and by optimizing operating conditions using statistical analysis, it was found that an optimal moisture content of 72%, substrate mixing ratio of 72.34:27.6 wt.%, and turning frequency of 2 times per week produced high-quality vermicompost with maximum yields of nitrogen (2.76%), phosphorus (1.80%), and potassium (1.88%). This study demonstrates that vermicomposting can effectively convert municipal sewage sludge into valuable agricultural input for sustainable management.

INTRODUCTION

Over the years, urbanization and rapid population growth have led to increased waste generation, particularly solid waste and bio-waste. An increase in population doubles the demand for water supply provision services, consequently increasing the generation of biosolid waste, such as municipal sewage sludge, produced by wastewater treatment plants. Annually, municipal wastewater treatment sectors produce an average of 45 million dry tons of municipal sewage sludge (Ferrentino et al., 2023). Factors such as an increase in population density, industrialization, changes in lifestyle, and urbanization are the primary factors contributing to an increase in waste generation in most urban cities.

Managing human waste following public health and environmental laws is becoming increasingly challenging. The United Nations has set Sustainable Development Goal 6.3 to improve water quality by reducing pollution, eliminating dumping, and minimizing the release of hazardous chemicals and materials. The goal is to halve the proportion of untreated wastewater and substantially increase recycling and safe reuse globally by 2030 (Mara & Evans, 2018). However, due to the pathogenic nature of sludge, proper handling, disposal, and end-use practices can be costly. Many developing countries in Africa lack the technical expertise and enforcement of environmental laws necessary to handle municipal sewage sludge. The operational and economic costs of managing sludge makeup 50% of wastewater treatment plant expenses, making it difficult to efficiently manage the sewage sludge generated (Gebreeyessus & Jenicek, 2016; Abdel Wahaab et al., 2020). Many developing nations resort to dumping sludge in dumpsites or water bodies, leading to water, air, and soil pollution. In water bodies, the excessive nutrients in sludge accelerate eutrophication, lowering dissolved oxygen levels and causing offensive smells. These practices are unsustainable and contribute to significant water, air, and soil pollution.

The management of human waste is a challenge, but it also presents an opportunity to benefit millions of poor farmers. Human excreta is rich in Nitrogen, Phosphorus, and Potassium (NPK), which are important nutrients for plant growth (Sakthivel, 2011). Wastewater reuse and waste composting have a long tradition dating back centuries (Cofie, 2016). Converting human waste into a resource can contribute to sustainable agricultural production. This solution can be scaled up to achieve Sustainable Development Goal 2, which aims to end hunger, achieve food security, promote sustainable agricultural systems, and improve nutrition by 2030 (Gil et al., 2019). This research used an ecological approach called vermicomposting to turn municipal sewage sludge which is a biowaste into a useful resource for agricultural practices. The study utilized municipal sewage sludge blended with coffee husk and cow dung via vermicomposting technology to produce high-quality compost.

MATERIALS AND METHODS

Study Area

The research study was carried out in Addis Ababa, the administrative capital of Ethiopia. Following Nigeria, Ethiopia has the second-highest population in Africa. Addis Ababa, as the administrative capital, has a large population, leading to a significant amount of waste being generated, including domestic waste such as domestic sewage.

There are twelve wastewater treatment plants in Addis Ababa, with the Kaliti Wastewater Treatment Plant (KWWTP) being one of the largest in terms of size. This KWWTP is located in the industrial area of Addis Ababa, between latitude 8°N and longitude 38°E. In Addis Ababa, around 40% of homes have a system for collecting sewage waste using piped sewer lines, while the remaining 60% use on-site sanitation methods. Sewage from on-site sanitation systems, such as septic tanks and pit latrines, is collected and delivered to the treatment facility in vacuum trucks for disposal every week. In addition to domestic waste, the treatment plant also receives waste from various institutions, including the healthcare and hospitality sectors in the city of Addis Ababa. The KWWTP uses a conventional method to treat its wastewater, which involves a series of units for preliminary, primary, secondary, and disinfection treatments. The plant utilizes the Up-Flow Anaerobic Sludge Blanket (UASB) reactor to break down organic pollutants using microorganisms in the sludge under anaerobic conditions.

Sewage sludge sampling

The study utilized granular sludge from the UASB reactor and sludge from the sludge drying beds. Composite sludge samples from four different locations on the sludge drying beds were combined to create a representative sample for the vermicomposting process. Granular sludge from the outlet of the UASB reactor was also collected to compare the physical and chemical characteristics of the sludge from the drying beds.

Materials used in the vermicomposting process

To balance the carbon-to-nitrogen ratio and speed up the decomposition process, additional agricultural waste was added to the dry municipal sewage sludges. Specifically, coffee husks from Hawassa City in Ethiopia and pre-composed cow dung were used. The coffee husks were shredded to reduce their particle size to 1-2 mm, which is the optimal size according to Gurav & Pathade, (2011). *Eisenia fetida* earthworms were used as the primary organic waste decomposers. These worms were obtained from the Ethiopia Agricultural Research Ambo plant protection research center, and this species is commonly used in vermicomposting studies, as noted by Ludibeth et al., (2012) and Degefe et al., (2012).

Experimental description

A pilot-scale vermicomposting experiment was set up in a greenhouse with ambient average temperatures at Addis Ababa University, School of Natural and Computational Sciences. The experiment lasted for a maximum of 50 days, following the guidelines of Biruntha et al. (2020). Each treatment unit contained sewage sludge substrate, cow dung, coffee husks, and earthworms in specified proportions. Control experiments were also conducted without earthworms in the substrate mixture to compare the effects of earthworms in the conversion of substrates.

Laboratory procedure and Statistical Analysis

The sewage sludge samples were analyzed in the laboratory to determine specific physical-chemical parameters. Additionally, during the vermicomposting process, selected chemical and physical parameters were investigated to gain a better understanding of the changes in the composting process. The statistical analysis employed Design-expert 10.0.7 (State-Ease) software for designing the experiment, conducting analysis of variance, and optimized using response surface methodology. The Box-Behnken experimental method under response surface methodology was used to optimize municipal sewage sludge vermicomposting parameters under three operating conditions: moisture content, turning frequency, and mixing ratio of substrates. The response variables focused on nutrient parameters such as nitrogen, phosphorus, and potassium.

RESULTS AND DISCUSSION

To efficiently valorize the sewage sludge or consider disposal options, it is necessary to characterize its physical, chemical, and biological composition. The characteristics of sewage sludge can vary significantly between different wastewater treatment facilities, and its composition depends on the nature of the treated sludge and the treatment technology used (Rorat et al., 2019). In this study, samples of sludge obtained from the sludge drying beds and granular sludge from the outlet of the UASB reactor were analyzed for characterization. The study provides a general overview of sewage characteristics based on sludge samples collected at a specific point in time.

Table 1: Selected physicochemical and biological characteristics of granular sludge from the UASB reactors

Parameters	Quantity/Units (Mean±SD)
pH	6.80 ± 0.03
Electrical Conductivity, (mS/cm)	2.05 ± 0.03
Total dissolved solids, (mg/L)	995 ±35
Moisture content (MC), (%)	96±1
Total solid, (%)	4±1
Heavy metals	
Cadmium	Below Detection limit
Lead, (mg/L)	0.010±0.001
Chromium, (mg/L)	0.910±0.001
Zinc, (mg/L)	21.69±0.70
Copper, (mg/L)	2.55±0.24
Bacteriological Parameters	
Total coliforms, (CFU/ml)	5.24×106
E. coli, (CFU/ml)	2.38×106

The granular sewage sludge samples obtained from the outlet of the UASB at the Kaliti wastewater treatment plant showed nearly neutral pH values (Table 1). This close-to-neutral pH is ideal for using sewage sludge in agriculture, as it won't significantly affect the pH of the soil, which in turn can impact nutrient uptake. The moisture content of the granular sludge was reported to be 96%, indicating that it is almost entirely liquid. However, liquids are heavy and difficult to transport and handle, so the sludge is usually dewatered. The method of dewatering affects the overall moisture variation between the granular and dry sludge samples. At KWWTP, sludge drying beds are used for dewatering the sludge.

Heavy metal analysis of the granular sewage sludge

The use of municipal sewage sludge in agricultural practices is limited by factors such as pathogens and heavy metals. An analysis was conducted to assess the health and environmental hazards of the municipal sludge from the Kaliti Wastewater Treatment plant. Heavy metal analysis was performed on five trace elements using flame atomic absorption spectrometry. These five heavy metals, including Cadmium, Lead, Chromium, Zinc, and Copper, are of primary concern due to their high toxicity levels, as indicated by previous studies (Águila-Juárez et al., 2011). According to the regulatory standards of the World Health Organization (2006), the levels of cadmium and lead were within permissible limits, while the levels of chromium and copper slightly exceeded hazardous levels by more than 0.86 mg/L and 0.55 mg/L, respectively, as shown in Table 1 Zinc, on the other hand, exhibited the highest concentration, surpassing regulatory limits by more than 6.69 mg/L. Since the wastewater treatment plant only handles municipal or domestic waste, the high concentration of Zinc may be attributed to the illegal discharge of industrial waste into the main sewerage network.

The results from the microbial analysis of the municipal sewage sludge samples, as shown in Table 1, indicated that the microbial biological community exceeded the recommended microbiological quality guidelines (WHO, 2006). Therefore, the use of untreated municipal sewage sludge and wastewater in agricultural practices may pose a significant health hazard to field workers and crop consumers. They could be at risk of helminthic infections, as well as bacterial infections such as typhoid and cholera. It is crucial to treat this sludge before reusing it.

To successfully use sludge as an organic fertilizer, the organic matter content of the sludge is an important parameter. Organic matter application in the form of sewage sludge improves water infiltration in the soil. The mean values of volatile solids of dry sludge samples obtained from the characterization study were 86.99% (Table 2), which reveals that the sewage sludge is rich in organic matter content. Values of the carbon to nitrogen ratio of the sludge were very low due to the higher nitrogen than carbon content sewage sludge contains. For the faster decomposition of organic waste, many authors suggest a carbon-to-nitrogen requirement of 20:1 to 30:1 (Ndegwa & Thompson, 2000). Proximate analysis of the sewage sludge samples of ash (Table 2) revealed that sewage sludge is rich biomass with much appreciable mineral or inorganic content, hence valorization can also be explored in other streams such as cement in the construction industry.

Table 2. Physicochemical and biological characteristics of the sludge samples obtained from the sludge drying beds

Parameter	Quantity/Unit (Mean±SD)
pH	7.42±0.06
Electrical conductivity (EC), (mS/cm)	3.56 ±0.02
Moisture content, (%)	71.78±0.03
Total solids (TS), (%)	28.22±0.03
Ash content, (%)	13.01±0.02
Volatile solids, (%)	86.99 0.02
Total Dissolved solid (TDS), (mg/L)	1005 ±1
Carbon content, (%)	29.78 ±0.01
Total nitrogen, (wt%)	0.94
Carbon to nitrogen ratio	31.7
Total coliforms, (CFU/ml)	4.34×106
Total fecal coliforms, (CFU/ml)	1.66×106
Helminth eggs, (per gram)	70 ±2

Sewage sludge vermicompost process and maturity of compost

The degradation of the sewage sludge and the interaction of earthworms and micro-organisms bring about significant physical and chemical changes in the compost (Amouei et al., 2017). By the 50th day of vermicomposting, the pH value of the compost dropped to neutral, indicating the stability and maturity of the compost, as humus has a pH buffering capacity. The temperature of the vermi-reactors or runs was kept within the optimum ranges required for vermicomposting. The minimum temperature value recorded during the vermicomposting process was 11.5°C, and the maximum value was 40°C. At the minimum temperature of 11.5°C during the first week of vermicomposting, the earthworms were immobile and not reproducing until the temperature of the vermi-reactors reached optimum values. The vermicompost of municipal sewage sludge amended with cow dung and coffee husks developed a dark black color with finely divided and homogenized crushed crumbs, indicating mature castings. This was observed towards the latter part of the vermicomposting period, in the 5th to 6th weeks of vermicomposting.

Fig 1. Pictures (a) and (b) Harvesting of the vermicompost in experimental bins; Picture (c) *Eisenia fetida* earthworms feeding on the biowaste

The qualitative analysis of the vermicompost showed that the municipal sewage sludge degradation by the *Eisenia fetida* earthworms was successful. The composite vermicompost obtained from all experimental runs had a dark, fine color and smelled similar to soil. A carbon to nitrogen ratio of 16:1 was recorded, indicating an advanced degree of stabilization of the organic matter and reflecting a satisfactory degree of maturity based on the guidelines for Assessing compost quality by Ozores-Hampton (2017). The composite vermicompost obtained in this study contained 2.84% nitrogen, 1.22% available phosphorus, and 1.57% potassium as the major three important elements. The nutrient analysis of the vermicast showed a carbon to nitrogen ratio of 12-15, a nitrogen range of 1.5-2.5%, a potassium range of 1.25-2.25%, and a phosphorus range of 1-2%, following the guidelines of Chaoui (2010). After treating the sludge using an ecologically friendly approach for 50 days, a high quality biosolid with relatively low contaminant levels was achieved. There was also a reduction in pathogen levels in the vermicompost compared to the initial sewage sludge samples. This reduction may have been attributed to the dilution of sewage sludge with other amendments, such as cow dung and coffee husks, which had reduced the toxicity levels. Earthworm and bacteria degradation mechanisms may also have led to the reduction of pathogens in the vermicompost, as they release antibacterial coelomic fluid (Sinha et al., 2010).

CONCLUSION

The findings of this study suggest that vermicomposting is an effective eco-friendly method for recycling bio-waste, particularly municipal sewage sludge. This process can convert potentially hazardous sewage sludge into safe organic fertilizer, suitable for agricultural use. Vermicomposting offers an ecological approach to managing waste in Africa. Additionally, the characterization results indicate that the valorization of sludge can be explored in other sectors, such as the construction industry, where the sewage sludge's appreciable ash content makes it suitable as a supplementary material for concrete. Vermicomposting can contribute to the sustainable management of biowaste, such as municipal sewage sludge, by transforming it into safe organic fertilizer, with earthworms playing a crucial role in the decomposition of organic waste. This technique is particularly viable for developing countries that may not have the resources for other sludge treatment alternatives, and it can help prevent pollution of soil, water, and land.

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A PANEL ARDL MODEL OF ENERGY UTILIZATION EFFICIENCY AND GREENHOUSE GAS EMISSIONS IN TOP FIVE EMITTERS IN AFRICA

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ABSTRACT

Greenhouse gas (GHG) emissions have been implicated as the major cause of global climate change. Policy makers have taken serious steps on the need for drastic reduction in global GHG emissions as amplified in the Paris Agreement. The dilemma facing many African countries in relation to the Paris Agreement is how to facilitate economic development given current high energy utilization without compromising the need for environmental conservation. This paper therefore analyzed the effect of energy utilization efficiency on GHG emissions among the five top CO_2 emitters in Africa - South Africa, Egypt, Nigeria, Algeria and Libya. The data were from the World Development Indicators (WDI) covering 1990-2020. The data were analyzed with panel Autoregressive Distributed Lag (ARDL) model. The results showed that all the included series were stationary at first difference. The optimum lag lengths were determined independently in Stata, and the most frequent lags across the countries were selected. Hausman test revealed that pooled mean group (PMG) estimation was preferred to other estimators. The long-run results showed that particulate damage, CO_2 intensity, and energy use intensity positively impacted emissions, while GDP per capita and renewable energy utilization produced mixed results. In the short-run, the error correction mechanism parameters were all significant ($p<0.01$) in Libya for all emission indicators, while Algeria showed significance ($p<0.01$) in total GHG and CO_2 per capita models. Particulate emission damages significantly reduced ($p<0.01$) total GHG emissions in Libya and Nigeria. Renewable energy significantly increased ($p<0.01$) GHG emissions in South Africa but reduced them in Nigeria. Also, CO_2 emission intensity significantly ($p<0.01$) and positively impacted GHG emissions in South Africa, Egypt, Libya and Nigeria. Electric power transmission losses increased total emissions and CO2 emissions in Libya and Algeria, respectively. It was concluded that initiatives to reduce GHG emissions should focus on developing countries' sensitivity to emission damages, and promotion of initiatives for using renewable energies. Also, promotion of energy efficiency across industries offers a prospect for ensuring environmental sustainability.

Key words: Greenhouse gas emission, sustainability, energy efficiency, renewable energy, Africa

INTRODUCTION

Climate change is a global development challenge that disproportionately affects developed and developing economies. Although developing economies are the least contributors to global emission of greenhouse gases (GHGs), they are going to be worst affected by their consequences. Periodic manifestation of several environmental hazards in the form of droughts, floodings, heat waves, wildfires, cyclones, and hurricanes are disastrous evidences that some drastic steps are needed to reduce GHG emissions (Reuters, 2023; European Environmental Policy Agency, 2023). The Paris Agreement has emphasized rapid decarbonization for the long-term reduction in global warming. The Agreement mandates signatory countries to come up with some comprehensive GHG emission reduction pathways in a Nationally Determined Contribution (NDC) (United Nations Framework Convention on Climate Change, undated). Therefore, the commitment of the world's leaders towards the Paris Agreement reflects the seriousness of the problem (United Nations, 2015).

In Africa, the consequences of climate change are manifesting in the form of droughts, flooding, and severe heat waves with significant social and economic consequences. Although Africa is among the least emitters in the world, the continent is not shielded from the negative consequences of emitted GHGs. Specifically, in 2022, the Asia-Pacific region emitted 17.96 billion metric tons of carbon dioxide which was higher than the amount emitted by the combination of other continents (Tiseo, 2023). Africa was the second lowest emitter with 1307 million metric tonnes of CO_2 (Tiseo, 2023). Carbon dioxide emission reduction in Africa requires specific focus on the top emitters, among which South Africa, Egypt, Nigeria, Algeria and Libya are notable. Specifically, South Africa is the topmost GHG emitter and the most industrialized economy in Africa. With fourteenth global ranking, GHG emission reduction is one of the major agendas of the South African government (Mcsweney and Timperly, 2018). Similarly, there is a perplexing inequity in CO_2 emissions within Africa, with South Africa, Egypt and Algeria accounting for more than 60 percent of the continent's total GHG emissions (AJlab, 2023).

Therefore, among their African counterparts, the challenge of decarbonization for absolute mitigation of climate change directly rests on some African countries. Specifically, as the highest emitter of GHGs in the continent (International Monetary Fund [IMF], 2023), South Africa, Egypt, Algeria, Nigeria, and Libya have some absolute responsibilities to address their economic development plans vis-a-vis the global challenge of decarbonization. In a bid to ensure compliance with the Paris Agreement, the South African Government has come up with a NDC which seeks to reduce GHG emissions to 350–420 $MtCO_2e$ by 2030 (IMF, undated). The Egyptian government has also developed a revised NDC, which seeks to reduce emissions from electricity, oil and gas and transportation by 37%, 65%, and 7%, respectively, by 2030. Similarly, total electricity generation from renewable sources is expected to be 42% by 2035 (United Nations Development Programme[UNDP], 2023).

On the Nigeria's part, the government plans to increase renewable energy composition in total energy utilization to 36% by 2030 (International Energy Agency, 2023a; International Energy Agency, 2023b). In accordance with the Paris Agreement, the country's Nationally Determined Contribution (NDC) seeks an end to gas flaring by 2030, and reduce methane emissions by 60% in 2031 (Climate Action Tracker, 2023; International Energy Agency, 2023c. The country will therefore conditionally and unconditionally reduce GHG emissions by 47% and 20%, respectively, in 2030 (NDC Partnership, 2023). Similarly, the Algerian government plans to reduce gas flaring to less than 1% by 2030 and ensure that 27% of the total electricity is generated from renewable sources (International Energy Agency, 2023d). Libya also seeks to reduce emission of GHG through increase in the renewable energy to 10% of the total energy generation by 2025 ((International Energy Agency, 2023e).

Moreover, decarbonization portends some negative economic consequences for many African countries. Specifically, South Africa heavily relies on coals and fossil fuels for energy generation, while Nigeria, Egypt, Algeria and Libya depend heavily on fossil fuels. Therefore, some basic initiatives for promoting energy utilization efficiency to ensure attainment of the global decarbonization agenda is imperative. Therefore, it is important to understand the effect of initiatives for the promotion of energy utilization efficiency on emission of GHGs among top GHG emitters in Africa. This study seeks to provide some policy relevant analyses on the linkages between energy utilization efficiency and GHG emissions in Africa's top emitters. It is hypothesized that selected indicators of energy use efficiency do not significantly influence emission of GHGs. The usefulness of this hypothesis for energy policy formulation and industrial development cannot be over-emphasized. Specifically, the introduction of alternative energy sources and technological innovations to facilitate reduction in energy consumption and gradual offset of people's dependence on coals and fossil fuels has been a welcomed development.

MATERIALS AND METHODS

Data Sources

The data for this study were obtained from the World Development Indicator database (World Bank, 2024). The data were for Egypt, South Africa, Nigeria, Algeria and Libya. The study covered the 1990-2020 periods. The selected variables and their units of presentation are presented in Table 1. It shows that for the five countries, average annual total emissions of GHG was 251,408.2 kt of CO_2 equivalent. The average annual per capita emission of CO_2 was 152,584.3 kt, while the average annual per capita CO_2 was 4.22 metric tonne. Average annual particulate emission damage was 2,294,178,638 and average annual percentage renewable energy usage was 21.49.

Table 1: Selected Variables and Descriptive statistics

Variable	Mean	Std dev	Minimum	Maximum	N
Total emission of GHG (kt of CO2 equivalent)	251408.2	127269.4	70056.86	555409.3	155
Carbon dioxide emissions (kt)	152584.3	116380.5	26342.3	448298.1	155
Per capita CO2 (metric ton per capita)	4.222229	3.056828	.491376	9.985813	155
Adjusted savings: particulate emission damage (current US$)	2.29e+09	3.52e+09	8.65e+07	1.53e+10	155
Per Capita GDP (current US $)	4025.27	3046.005	494.1292	15765.42	155
Renewable energy consumption (%)	21.49052	32.17909	.06	88.68	155
CO2 intensity (kg per kg of oil equivalent energy use)	2.406893	.7574867	.6664634	3.341033	125
Electric power transmission and distribution losses (% of output)	18.32685	12.3474	5.865399	69.69601	125
Electric power consumption (kWh per capita)	1756.436	1534.493	74.14613	4766.652	125
Energy use (kg of oil equivalent per capita)	4371692	6818902	0	2.27e+07	155

Empirical Model

This study used the panel Auto-Regressive Distributed Lagged (ARDL) model. The model is generally specified as:

Yit=j=1piYi,t-j+j=0qijXi,t-j+i+it 1

Where Yit is the dependent variable, Xi,t is a kx1 vector of independent variables that are I(0) or I(1), i is the coefficient of the lagged dependent variable, ij are the coefficients of the independent variables, i is the unit specific fixed effect and it is the error term.

The estimated Error Correction Model (ECM) ARDL is specified as:

ΔYit=j=1p-1siΔYi,t-j+j=0qi1kijΔXi,t-j+ϑiECT+θi+it 2

ECT is error correction term = Yit-1-iXit, ϑi is the group specific speed of adjustment coefficient (ϑi<0), si and kij are the short run dynamic coefficients, i is a vector of long run coefficients. The Yit and Xitare presented in Table 1.

RESULTS AND DISCUSSION

Tests for Unit Root

The results of the tests for unit root are presented in Table 2. The results showed that except CO_2 intensity, all the variables were not stationary at level. However, they were all stationary at first difference. This implies that the variables were either I(0) or I(1). This is the basic requirement for using ARDL model.

Table 2: Results of the Tests for Stationarity

Dependent variables	Z-t-tilde-bar		Stationarity Level;
	Level Data	1st Difference	
Total emission of GHG (kt of CO2 equivalent)	0.1951	-6.070***	I(1)
Carbon dioxide emissions (kt)	0.0125	-5.815***	I(1)
Per capita CO2 (metric ton per capita)	0.2690	-5.946***	I(1)
Adjusted savings: particulate emission damage (current US$)	-1.2433	-6.2460***	I(1)
Per Capita GDP (current US $)	-0.7741	-5.6506***	I(1)
Renewable energy consumption (%)	-0.8698	-6.2226***	I(1)
CO2 intensity (kg per kg of oil equivalent energy use)	-1.8801**	-6.0525***	I(0)
Electric power transmission and distribution losses (% of output)	-1.6321	-6.5248***	I(1)
Electric power consumption (kWh per capita)	0.7499	-5.2457***	I(1)
Energy use (kg of oil equivalent per capita)	0.5302	-6.5494***	I(1)

Note: ** - statistically significant at 5% level, *** - statistically significant at 1% level.

Results of Hausman Test and Estimated Panel ARDL Regression

The Hausman tests were conducted on the mean group (MG), pooled mean group (PMG) and dynamic fixed effect (DFE) models. The results were unanimously in favour of pooled mean group (PMG). Therefore, the PMG estimator was used in this study. The results in Table 3 show the short-run and long-run parameters of the pooled regression. The long-run parameters showed that the particulate emission damage parameters are with positive sign in all the results, although that for CO_2 emissions did not show statistical significance ($p>0.05$). The results showed that in the long-run, increase in particulate emission damage will significantly ($p<0.01$) increase total GHG emissions and CO_2 per capita emissions. Moreover, in the long-run, increase in per capita GDP will significantly ($p<0.05$) reduce GHG emissions and CO_2 Emissions. The parameters of renewable energy were with negative and positive signs in the total GHG and CO_2 emissions models, respectively. The results showed that in the long-run, increase in the renewable energy will reduce total GHG emissions, but increase CO_2 emissions. CO_2 intensity parameters were all with positive sign and statistically significant ($p<0.01$). These parameters imply that increase in CO_2 intensity will lead to increase in all the indicators of GHG emissions. In addition, in the long run, increase in electric power transmission losses significantly reduced total GHG emissions. Table 3 also shows that out of the short-run parameters, only energy use is significant ($p<0.01$) in the total GHG emissions model.

The short run parameters for each country are presented in Table 4. The results showed that the error correction parameters in the total GHG emissions model for South Africa (-0.0545) and Libya (-1.1123) are significant ($p<0.01$), while those for Nigeria (-0.0335) and Algeria (-0.0432) are significant at 10% level. These results showed that a deviation from long-run equilibrium in total GHG emissions will be corrected at the 5.45%, 111.23%, 3.35% and 4.32% adjustment speeds in South Africa, Libya, Nigeria and Algeria, respectively. In CO_2 emissions model, only the ECT parameter for Libya (-0.2199) and Algeria (-0.5801) were significant ($p<0.01$), while those for Egypt (-1.4454), Libya (-0.3688) and Algeria (-0.5851) were significant in the CO_2 per capita model. These results showed that any deviations the long-run equilibrium in the CO_2 model will be corrected at 21.99% and 58.01% adjustment speeds in Libya and Algeria, respectively. Also, deviations from long-run equilibrium in CO_2 per capita model will be corrected at 144.54%, 36.88% and 58.51% adjustment speeds in Egypt, Libya and Algeria, respectively.

Furthermore, in the short-run, increase in particulate emission damages will significantly reduce ($p<0.01$) total GHG emission in Nigeria and Libya, while it will significantly reduce ($p<0.01$) CO_2 emissions in Algeria and increase it in Egypt. In the CO_2 per capita model, increase particulate emission damages will significantly reduce ($p<0.01$) emissions in South Africa. Table 4 further shows that per capita GDP is significantly ($p<0.05$) and positively associated with total GHG emissions in Nigeria and Libya. Also, in Egypt and Algeria, CO_2 emissions was positively and significantly impacted by per capita GDP, while it impacted per capita CO_2 significantly in South Africa. The parameters of renewable energy utilization were positive and significant ($p<0.01$) in South Africa. Same result was obtained for Libya. These showed that an increase in renewable energy utilization increased all the indicators of CO_2 emissions. Moreover, in Nigeria, renewable energy utilization significantly reduced CO_2 and CO_2 per capita emissions.

CO_2 emission intensity significantly and positively impacted all the indicators of GHG emissions in South Africa. In Nigeria and Egypt, total GHG emissions were significantly and positively impacted by CO_2 intensity. In Libya and Egypt, CO_2 emission and CO_2 emission per capita were positively impacted by CO_2 intensity. The parameters of electric power consumption per capita are negative and significant ($p<0.01$) for all indicators of emissions in Nigeria. These imply that increase in per capita electric power reduced GHG emissions. In Algeria, this parameter is significant for CO_2 emissions model and with negative sign. Electric power transmission losses increased total emissions and CO2 emissions in Libya and Algeria, respectively.

Table 3: Pooled Mean Group Estimators for the Five Countries

	Coefficient	z-stat	Coefficient	z-stat	Coefficient	z-stat
	Total GHG Emissions (CO_2)		CO_2 Emission		CO_2 Per Capita Emission	
Long-run parameters						
Particulate emission damage	.3607836***	10.87	.2200309*	1.64	.0345715***	2.72
Per Capita GDP	-.2746584***	-8.89	-.2910779**	-2.48	-.0171569	-1.49
Renewable energy	-.3957924***	-9.00	.0779536***	3.36	-.0221577	-1.23
CO2 intensity	.879187***	6.62	1.819697***	6.27	.6981871***	21.88
Electric power losses	-.1682268***	-10.68	-.0599634	-0.91	-.0019499	-0.47
Electric consumption per cap	.3858025***	11.82	.6664825***	13.30	.0626771***	4.51
Energy use	1.080387***	8.86	1.573134***	7.41	.868651***	48.22
Short-run parameters						
ECT	-.245305	-1.13	-.1684525	-1.51	-.4865353*	-1.85
D1.Particulate emission damage	-.1079988*	-1.83	-.0815494	-0.92	-.0562276*	-1.93
D1.Per Capita GDP	.0760765*	1.72	.0877964	0.90	.0452095	1.37
D1.Renewable energy	.0310692	0.31	-.5647743	-1.04	-.4575886	-1.04
D1.CO2 intensity	.2840663*	1.66	.4145299*	1.76	.3536287*	1.64
D1.Electric power losses	.067025	1.10	.0238033*	1.81	.0133299	1.54
D1.Electric consumption per cap	.0374713	0.56	-.0871735	-1.57	-.0334245	-0.61
D1.Energy use	.5606423***	4.61	.6885559***	3.20	.4830668*	1.76
Constant	-.4578409	-1.06	-.5877135	-1.54	-1.410047*	-1.83

Table 4: Country Level Short-Run Parameters for the PMG Model

	Coefficient	z-stat	Coefficient	z-stat	Coefficient	z-stat
Egypt	Total GHG Emissions (CO_2)		CO_2 Emission		CO_2 Per Capita Emission	
ECT	0.0169	0.75	0.0241	1.55	-1.4454***	-7.92
D1.Particulate emission damage	-0.0073	-0.10	0.1053**	2.47	-0.0084	-0.25
D1.Per Capita GDP	0.0144	0.24	-0.0748**	-2.04	-0.0219	-0.83
D1.Renewable energy	0.0496	0.99	-0.0077	-0.26	-0.0123	-0.52
D1.CO2 intensity	0.4651***	4.20	0.8226***	12.26	-0.2570*	-1.77
D1.Electric power losses	0.0006	0.05	-0.0013	-0.18	0.0042	0.86
D1.Electric consumption per cap	0.0127	0.13	0.0410	0.69	0.0543	1.04
D1.Energy use	0.6291***	10.10	0.9275***	22.13	-0.3783**	-2.31
Constant	0.0303	1.11	0.0870*	1.67	-4.2230***	-7.19
South Africa						
ECT	-0.0545***	-3.50	-0.0044	-0.60	0.0048	1.42
D1.Particulate emission damage	0.0187	0.65	0.0117	0.50	-0.0073***	-3.13
D1.Per Capita GDP	-0.0214	-0.78	-0.0138	-0.62	0.0068***	3.03
D1.Renewable energy	0.0331**	1.98	0.0355***	2.89	0.0023*	1.79
D1.CO2 intensity	0.7282***	30.93	0.9650***	46.92	1.0058***	302.65
D1.Electric power losses	-0.0031	-0.42	0.0008	0.12	0.0006	1.02
D1.Electric consumption per cap	0.0222	1.01	0.0116	0.62	-0.0020	-1.03
D1.Energy use	0.7487***	27.81	0.9726***	45.23	1.0046***	286.44
Constant	-0.0790*	-1.90	-0.0114	-0.39	0.0138	1.45
Nigeria						
ECT	-0.0335*	-1.73	-0.0619	-1.43	-0.0382	-0.69
D1.Particulate emission damage	-0.0628**	-2.28	-0.0449	-0.97	-0.0572	-1.24
D1.Per Capita GDP	0.0345**	2.32	0.0307	1.24	0.0307	1.22
D1.Renewable	-0.2963	-0.63	-	-3.38	-2.2238***	-2.80

energy			2.7435***			
D1.CO2 intensity	0.2534**	2.35	0.1450	0.65	0.3346*	1.89
D1.Electric power losses	0.0188	1.23	0.0257	1.02	0.0156	0.64
D1.Electric consumption per cap	-0.1481***	-2.90	-0.2373***	-2.86	-0.2476***	-2.92
D1.Energy use	0.8691***	3.03	0.9858**	2.11	1.0698**	2.22
Constant	0.0035	0.17	-0.1262	-1.01	-0.1174	-0.72
Libya						
ECT	-1.1123***	-12.18	-0.2199***	-2.94	-0.3688***	-3.59
D1.Particulate emission damage	-0.2898***	-5.94	-0.0625	-0.65	-0.0422	-0.48
D1.Per Capita GDP	0.1316***	5.38	0.0273	0.47	0.0410	0.75
D1.Renewable energy	0.3457***	7.69	-0.0962	-1.00	-0.0524	-0.56
D1.CO2 intensity	-0.3126***	-2.93	0.4741**	2.43	0.5954***	3.45
D1.Electric power losses	0.3099***	8.75	0.0223	0.31	0.0002	0.00
D1.Electric consumption per cap	0.2678***	2.97	-0.0560	-0.28	-0.0051	-0.03
D1.Energy use	0.2938*	1.80	0.7065***	4.20	0.6080***	3.74
Constant	-2.1804***	-3.05	-0.9792**	-2.18	-1.0344***	-3.56
Algeria						
ECT	-0.0432*	-1.73	-0.5801***	-7.67	-0.5851***	-4.18
D1.Particulate emission damage	-0.1987	-0.86	-0.4174***	-3.11	-0.1659	-0.91
D1.Per Capita GDP	0.2213	1.04	0.4695***	3.54	0.1694	1.02
D1.Renewable energy	0.0232	1.15	-0.0119	-1.06	-0.0018	-0.11
D1.CO2 intensity	0.2863	1.59	-0.3341**	-2.49	0.0893	0.57
D1.Electric power losses	0.0089	0.20	0.0715***	3.04	0.0460	1.29
D1.Electric consumption per cap	0.0328	0.25	-0.1950**	-2.24	0.0333	0.31
D1.Energy use	0.2625*	1.95	-0.1495	-1.04	0.1113	0.67

Constant	-0.0635	-1.35	-1.9087***	-2.64	-1.6893***	-4.06

CONCLUSION

The results of data analyses have shown the contributions of energy utilization efficiency to different indicators of GHG emissions among top five emitters in Africa. The implications of the results are quite remarkable for policy initiatives to facilitate compliance with the Paris Agreement. Specifically, the adjustment speed to equilibrium deviations differed. Therefore, each country would respond to emission destabilization with different speed and progress. Promotion of economic growth measured as GDP per capita will facilitate long-run reduction in GHG emissions. There is also the need to promote renewable energy utilization as a way of reducing GHG emission in the long- and short-runs. In addition, efforts to reduce GHG emission intensity will facilitate reduction of GHG emissions.

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WASTE CHARCOAL CIRCULARITY FOR AFRICA: THE PRACTICE OF THE COMMUNITIES IN TANZANIA

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ABSTRACT

Forests are essential for energy, biodiversity, and many people's means of subsistence. African culture and customs have always included the use of biomass fuel from forests and woodlands. The continent, which produces 67% of the world's charcoal, has several difficulties in producing charcoal, one of which is the low efficiency of the earth kilns used to turn wood into charcoal. This is the major cause of waste charcoal in Tanzania, which contributes significantly to pollution. The objective of this paper, therefore, was to investigate the practice of local communities to transform waste charcoal by leveraging circularity technologies for improved energy efficiency using data collected through interviews with 298 randomly selected households. The data analysis was conducted using IBM SPSS statistics version 20 cross-tab tools. One hundred fifty (150) kg is the approximate amount lost as a result of waste charcoal produced in more than 50% of households. Of these, only 65 kg are recycled, leaving the remaining 85 kg disposed of illegally in dumpsites, which may have an impact on household income, pollution, public health, deforestation, and increased fuel prices. Comprehending the circularity of waste charcoal and related solutions to reduce greenhouse gas emissions is crucial for the sustainable livelihoods of communities in the Kilosa district of Tanzania. As such, the study offers policymakers a foundation upon which to implement circularity strategies for waste charcoal in order to tackle energy-related issues and eventually improve environmental health for sustainable development in Tanzania and elsewhere with similar environments.

Key words: *circularity; custom; green entrepreneurship, pollution; Kilosa; waste.*

INTRODUCTION

The scholars of circular economy Lemille (2021), describe circularity as the new model of the economy in Africa that seeks to combine available resources and innovation to circulate as much as possible for both economic and environmental benefits. However, the circularity approach has been ignored, largely because of resource availability. Together with firewood, charcoal is the main source of energy used for cooking Ngowi (2023) and a source of income among informal households in Marandu (2021) in Tanzania. *While* Africa *remains* the main producer of wood charcoal *resources,* accounting for two-thirds of all global charcoal produc*tion Ngowi and Ngalawa (2023), i*ncreasing dependence on wood biomass fuel and growing climate change have increased pressure on the degradation of forests and woodlands (Kilahama, 2008) and have impacts on those who are spending energy and time in the collection of firewood. By so doing, those involved in the process, particularly women and young girls, consume time, impeding their opportunities for income, education, and farming, among others (Khedari et al., 2003). Studies MNRT (2015) show earth kilns, with a low efficiency of about 16% been used in the process of turning wood into charcoal, have increased quantities of waste charcoal Ngowi and Ngalawa (2023) produced in many developing countries and Tanzania is no exception. With Tanzania's population expected to reach 134.0 million people by 2050, efforts to reduce biomass dependence have been limited, especially in rural areas facing knowledge, skills, technical, and social limitations and ill health threats due to pollution. Circularity technology reduces biomass dependence; clean the environment, and offers access to recycled briquettes for cooking. Despite the widespread use of charcoal, waste charcoal remains underutilized and unlawful dumped in landfills, therefore increasing public health risks (Figure 1).

Fig. 1. Unlawfully dumped waste charcoal in landfills (a) and human residents (b) (Ngowi, 2023).

Circular economy is facilitated by number of factors: policy, technology, financing, and partnership. Recycling of waste charcoal been one of the approaches of upscaling circularity in Africa, is the technology which utilizes small particles and or wood scraps, mixed with clay soils to produce briquettes. The later helps manage waste charcoal from the environment by converting it into useful energy source for household use and public health risk reduction. With Tanzania's sole source of wood biomass energy (i.e., forests and woodlands), facing degradation Kilahama (2008), climate change impacts, and human population growth rates, circularity technology provides a resource-efficient solution for producing waste charcoal recycled briquettes. Ngowi (2023), shows that nearly half of the studied households produce 150 kg of waste charcoal and only 65 kg are recycled, leaving 85 kg disposed of in open areas a potential environmental health risk. Also Ngowi and Ngalawa (2023) have investigated waste charcoal in the rural and peri-urban communities of East Central Tanzania and show that many households do throw away waste charcoal other than recycling it. Despite the availability of waste charcoal, literature on circularity technology has been limited and where available circularity is not being utilized to its full potential due to funding, knowledge, skills, technical, and social limitations (Ngowi and Ngalawa 2023). Therefore, this paper aims to address these shortcomings by trying to understand the practice of local communities to use circularity technologies to recycle waste charcoal into briquettes as useful energy source among Tanzanians in the rural and peri-urban households.

METHODOLOGY

Study Area

The Kilosa District, which had 617,032 residents in the Tanzania National Bureau of Statistics 2022 report, was the study location, conducted between 2021 and 2023 (NBS 2023). Information from Figure 2 shows that the study area is situated between 5°55' and 7°53' S and 36°30' and 37°30' E. Three ecological zones can be found in the district: lowlands (550 m), highland plateaus (1100 m), and mountains (2200 m). The socio-economic activities in the area are determined by these agro-ecological zones. Ishengoma et al., (2016), cited in Ngowi (2023), indicate that the district's primary vegetation is Miombo woodland, which is primarily composed of village forests (88,879 ha), central government forests (66,517 ha), district council forests (8,168 ha), and plantation forests (1,692 ha). It was therefore anticipated that these drivers would be relevant to the production of waste charcoal and therefore provide lessons learned about the significance of circularity.

Study design and data collection

The case study design for quantitative and qualitative data was adopted. Secondary data involved a review of published works. A questionnaire was used to collect data on the quantity of waste charcoal produced. The 208 heads of representative households were chosen using a straight-forward random selection procedure to ensure that the population of the area is represented based on the sampling procedure (Israel, 1992).

$$n = \frac{N}{1 - Ne^2}$$

In the formula, *n* is the sample size, N is the number of households, and 5% is the sampling error. Some of the key questions included in the questionnaire were: What is the quantity of waste charcoal produced in the households? What is the practice of the community regarding waste charcoal circularity? What are the main limitations of waste charcoal circularity? Are there instruments for managing waste charcoal?

Data Analysis

The survey data was analyzed using SPSS version 20 software through cross tabulation. The template technique was used to evaluate data gathered from focus group conversation and transect walks (Ngowi, 2018). Nonetheless, remarks and plates selected from FGD were included to the survey data.

RESULTS

The quantity of waste charcoal produced in homes

The data in Figure 2 illustrates the different amounts of waste charcoal produced in a household per year. The amount wasted as a result of waste charcoal produced by 58% of homes is 150 kg., with roughly 98% of those surveyed reported not having access to recycled charcoal briquettes.

Practice on waste charcoal circularity

The results in Figure 3 show that the majority of those surveyed (64%) stated that waste charcoal is useless and is unlawfully disposed of in landfills. The majority of those surveyed (57.7%) stated that there is no shortage of waste charcoal that can be recycled, yet 85.2 percent of them said that waste charcoal circularity is unregulated. However, the majority of respondents (93.6%) indicate that waste charcoal is segregated at the point of origin.

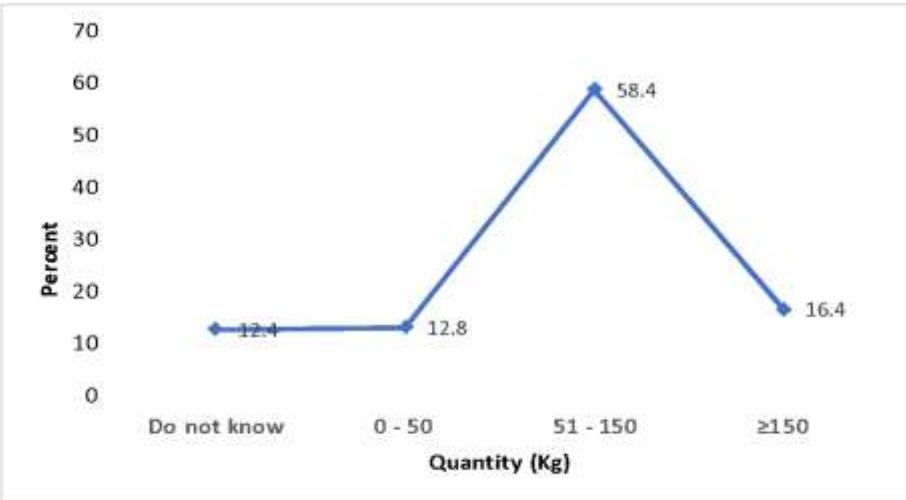

Fig. 2. Quantity of waste charcoal produced in homes

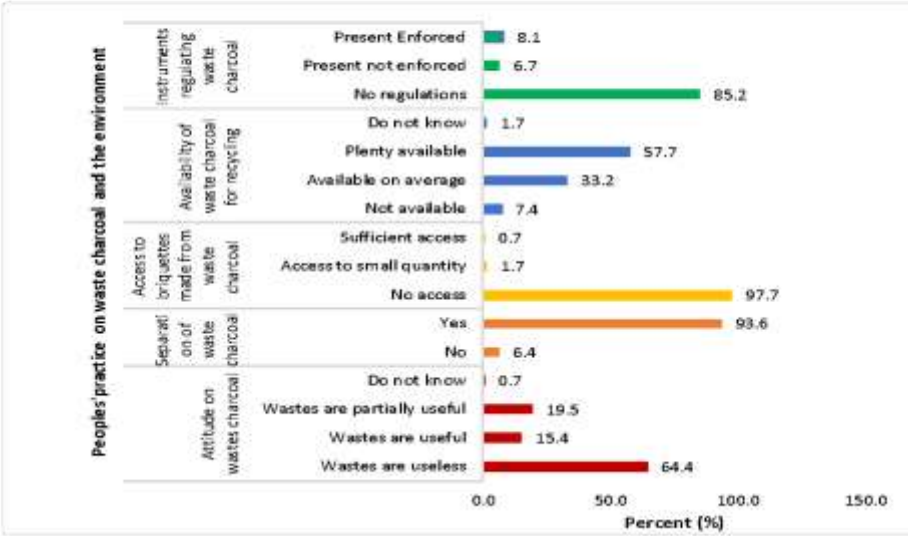

Fig. 3. Peoples practice on waste charcoal and regulation

DISCUSSION

The results show that despite the fact that more than 58% of families produce 150 kg of waste charcoal annually, people do not use it because they believe it does not generate enough heat energy for their use and is difficult to contain in cooking stoves (Ngowi, 2023). These findings are similar to the observation by Lemille (2021), who indicated that the shift from the narrations of plenty of resources is affecting the adoption of recycling shifts elsewhere in Africa. However, insufficient training in circularity technology is likely to influence a change in the behavior of the populace to respond best to the models they got trained on by recycling garbage and engaging in "green entrepreneurship." Ngowi (2023) provided a more extended benefit of waste charcoal circularity and wrote that leftover charcoal would reduce the frequency of tree harvests, increase alternative energy, and reduce localized pollution, especially in areas with no regulatory institutions. The author shows that the circularity of waste charcoal is critical to providing a comprehensive and supportive solution to environmental degradation. Furthermore, the study recommended six steps by which leftover charcoal can be locally converted to briquettes for use in cooking. However, the precaution was until the proposed approaches were fully validated, as the steps could vary along the landscape. Using leftover charcoal has many benefits, including being an easily accessible cooking fuel in homes. Ngowi and Ngalawa (2023) reported that households are worried that waste charcoal does not generate enough heat energy or is contained in cooking stoves. Nevertheless, as more information becomes available on circularity's benefits and as more people experience the positive outcomes of recycling, the initial negative reaction gradually fades.

CONCLUSION

This paper demonstrated that the use of wood biomass has existed throughout African history, but technological advances in the energy industry would likely make people practice it. By incorporating circularity into their systems to promote green growth, African forest and energy institutions are poised for a revolutionary age. It is imperative that individuals get ready for the adoption of circularity, but this preparation must be informed and grounded in data. Academics in particular are expected to lead communities into innovation, but they also need to stay up-to-date with the latest circularity technologies. It is recommended that, following increasing the caliber of research and shifting local community attitudes toward leftover charcoal through awareness-raising to improve understanding of circularity, institutional preparedness to exploit its transformative powers, understanding of potential misuse, and having in place appropriate corrective measures before problems arise,.

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IMPACT OF POULTRY WASTE MANAGEMENT TECHNIQUES ON POULTRY FARMERS' INCOME IN SOUTHWEST, NIGERIA

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ABSTRACT

Poultry waste is usually a combination of poultry bird's faeces, urine, saw dust and remnants of animal feeds, drugs and pesticides. Issues related to the environment, human health and the quality of life for people living near to and distant from poultry production operations make waste management a critical consideration for the long-term growth and sustainability of poultry production in larger bird facilities located near urban and peri-urban areas, as well as for smaller commercial systems associated with live bird markets, and for village and backyard flocks located in rural areas. This study was carried out to identify the impact of poultry waste management techniques on poultry farmers' income in southwest Nigeria. A multistage sampling technique was used for the selection of 600 poultry farmers, out of which 493 were used. The data were collected with the use of a well-structured questionnaire. The data were analyzed with the use of descriptive and inferential statistics. The inferential statistics employed was logit regression model. The result of the Logit regression model shows that age, educational status, household size, production system, flock size the technique adopted and labor were found to be important variables that could affect the income of the poultry farmers in the study area. It was concluded that if poultry waste is properly managed could increase the income of the poultry farmers.

***Key words**: Farmers' income, Logit regression, Management, Poultry waste, Techniques*

INTRODUCTION

The poultry industry is growing rapidly and contributes towards addressing key national development goals, as well as, in improving the standard of living of people through poverty alleviation and creating employment opportunities (Agblevor et al., 2010). Roeper et al. (2005) contended that the problem coming along with the poultry production is the manure that needs to be taken care of, as a non-appropriate treatment or disposal can become risky for environment and humans. For instance, manure can support the spread of diseases and may pollute soil and groundwater resources if not properly handled.

Waste is defined as anything that is no longer useful and needs to be disposed. Furthermore, waste may be defined by the type and place in which it is produced, such as agricultural, household, industrial and mining (Ministry of Local Government, Lands and Housing, 1998). Poultry waste is usually a combination of poultry bird faeces, urine, saw dust and remnants of animal feeds, drugs and pesticides (Adedayo, 2012). Poultry manure contains high phosphorus which has positive effect on the growth and productivity of crops. It is also effective when combined with mineral phosphorus fertilizer for farm use (Mokwunye, 2000). Dead birds and hatchery waste are high in protein and contain substantial amounts of calcium and phosphorus due to high levels of mineral supplements in the diet. The approximated percentages of nutrient intake excreted by poultry are: nitrogen (65.5%), phosphorus (68.5%) and potassium (83.5%), elements for soil fertility and increased crop production (Olumayowa and Abiodun, 2011).

The poultry industry produces large amounts of waste that include solid waste and wastewater. The solid waste consists of bedding material, excreta (manure), feed, feathers, hatchery waste (empty shells, infertile eggs, dead embryos and late hatchlings), shells, sludge, abattoir waste (offals, blood, feathers and condemned carcasses) and mortality. The wastewater results from washing and disinfection of chicken houses and abattoirs. Dong and Tollner (2003) stated that poultry densities on farms continue to increase and have caused manure related problems which are water, air and land pollution.

Poultry meat and eggs provide affordable, quality food products that are consumed by most ethnic populations worldwide. Advances in knowledge and technology over recent decades favour the growth and intensification of poultry production in developing countries where there are increasing human populations and economic constraints. Issues related to the environment, human health and the quality of life for people living near to and distant from poultry production operations make waste management a critical consideration for the long-term growth and sustainability of poultry production in larger bird facilities located near urban and peri-urban areas, as well as for smaller commercial systems associated with live bird markets, and for village and backyard flocks located in rural areas.

Many works had been done on the methods and ways of managing poultry waste, but there are few works that have taken into consideration the impact of the various methods used on the profit of the farmers in the study area. This research thereby showed the nexus between the various techniques adopted by the farmers and their profit.

MATERIALS AND METHODS

The Study Area

The study was carried out in the southwest region of Nigeria. Southwest Nigeria consists of Lagos, Ogun, Oyo, Osun, Ondo and Ekiti States, collectively known as the South-West geographical zone of Nigeria. The area lies between longitudes 20 311 and 60 001East and latitudes 60 211 and 80 371N, with a total land area of about 77,818 km2. It is bounded in the east by Edo and Delta States, in the north by Kwara and Kogi States, in the west by the Republic of Benin and in the south by the Gulf of Guinea. The climate of Southwest Nigeria is tropical in nature and is characterized by wet and dry seasons. The mean temperature ranges between 21^0 C and 34^0 C, while the annual rainfall ranges between 150mm and 3000mm. The wet season is associated with the southwest monsoon wind from the Atlantic Ocean while the dry season is associated with the northeast trade wind from the Sahara-desert, Ojo, et al; (2019).

A multistage sampling technique was used for the selection of poultry farmers. The first stage involved purposive selection of three states (Ogun, Oyo and Osun), the second stage involved a purposive selection of two Agricultural Development Programme (ADP) zones from each of the state. The third stage was the purposive selection of two blocks per zone based on the concentration of poultry farmers. The fourth stage consist the random selection of five farming cells from each of the block making a total of sixty (60) farming cells.

Lastly, ten poultry farmers were randomly selected from each farm cell giving a total sample size of 600 poultry farmers. The data were collected through the administration of a well-structured questionnaire on a cross-section surveyed of poultry farmers in the study area.

Sources and Types of Data

Primary data was used for this study. Primary data which involved the use of cross-sectional data was sourced with the aid of structured questionnaire through an interview schedule.

Method of Data Analysis

The data collected were subjected to descriptive and inferential statistics. The descriptive statistics are frequency and percentages. These were used to capture the demographic characteristics of the farmers, and also to describe the types and quantities of poultry wastes that were generated by the poultry farmers. While the inferential statistics employed was logit regression model.

The model is expressed mathematically thus;

$$\text{Logit}\ (Y_{ij}) = \alpha + \beta_1 X_1 + \ldots\ldots\ldots + \beta_{12} X_{13} + e_i \ldots\ldots\ldots \qquad (1)$$

where,

Y = poultry farmer's income (the product of output and price)
X_1 = Age (in years); X_2 = Sex; X_3 = Marital Status; X_4 = Household Size (in numbers)
X_5 = Educational Status (in years); X_6 = Farming Experience (in years); X_7 = Production System
X_8 = Flock Size (in numbers); X_9 = access to extension service (access = 1 otherwise 0)
X_{10} = Number of farm labour (Family and Hired) (Man- day); X_{11} = Access to credit (access = 1 otherwise 0); X_{12} = Quantity of litters (in kg); X_{13} = waste management techniques
e_i = Random (stochastic) factor external to the model

RESULTS AND DISCUSSION

This section deals with the interpretation of the results of the obtained from the study. Table one shows the socio-economic characteristics, while table two shows the inferential results of the study. Table 1 shows the socio-economic characteristics of the poultry farmers in southwest Nigeria. It was observed that majority of the poultry farmers in the study were young with about 70% of them less than 45 years of age.

Table 1: Socio-Economic Characteristics of Poultry Farmers in the Study Area

Item		
Age (years)	Frequency	Percent
15 – 25	97	19.7
26 – 35	149	30.2
36 – 45	138	28.0
46 – above	109	22.1
Total	493	100
Marital Status	Frequency	Percent
Single	170	34.5
Married	323	65.5
Total	493	100.0
Household Size	Frequency	Percent
1 – 5	403	81.7
6 – 10	90	18.3
Total	493	100.0
Educational Status	Frequency	Percent
Primary	17	3.4
Secondary	170	34.5
Tertiary	306	62.1
Total	493	100.0
Experience	Frequency	Percent
1 – 5	166	33.7
6 – 10	168	34.1
11 – 15	73	14.8

16 and above	86	17.4
Total	493	100.0
Production System	Frequency	Percent
Battery Cage	309	62.7
Deep-Litter	172	34.9
Free-Range	12	2.4
Total	493	100.0
Flock Size	Frequency	Percent
< 200	53	10.8
200 – 4999	266	54.0
5000 – 19999	117	23.7
>20000	57	11.5
Total	493	100.0
Sex	Frequency	Percent
Male	395	80.1
Female	98	19.9
Total	493	100.0
Extension Visit	Frequency	Percent
Never	246	49.9
Monthly	105	21.3
Quarterly	137	27.8
Annually	5	1.0
Total	493	100.0
Types of Labor	Frequency	Percent
Hired Labor	169	34.3
Family Labor	152	30.8
Both	172	34.9
Total	493	100.0

A large number of the respondents were married, showing that family labor may not be problem owing to the fact that most of the poultry farmers are married.

Table 1 also shows the household size (HHS) of the respondents, 81.7% of the respondents had a household size within the range of 1 – 5, while 18.3% of them had a range between 6 – 10 persons. Education has been seen as an important factor in agricultural activities. For instance, John et al; (2020) opined that an increase in the educational level of farmers will increase their technology adoption rate and also increase their sources of income by diversifying their livelihoods. Majority of the poultry farmers in the study area had tertiary (62.1%) education, 34.5% had secondary education, while only 3.4% of them had primary education.

The farming experience of the poultry farmers was captured by table 1. It was observed that 33.7% of the respondents had at least 5 years of farming experience. About 34.1% of the farmers had been in the business for between 6 and 10 years, while 14.8% of the farmers had between 11 and 15 years of experience, 17.4% of them had 16 years and above farming experience.

The poultry farmers in the study area produces their birds mostly (62.7%) with battery cage system, while only 2.4% of them uses free-range system, the remaining 34.9% uses deep litters. This deep litter system was found to be common among the broiler's farmers.

According FAO, (2008), the poultry industry was divided into small scale i.e flock size ranging from 1 – 199 birds, medium scale from 200 – 4999 and large scale from 5000 and above. It was observed from table 1 that more than 50% of the poultry farmers in the study area were operating on the medium scale (54.0%), 35.2% of them were large scale poultry farmers, while only 10.8% of them were small scale poultry farmers.

Majority (80.1%) of the poultry farmers were male, while 19.9% were female. This could be due to the involvement of the female folks in the marketing of the farm produce.

Extension visitation was found to be very poor in the study area. This could be due to either of these factors, this first could be to the high educational level of the farmers since most of them could surf the internet for more information, and secondly it could be due to lack of extension agents on waste poultry waste management.

The poultry farmers employed various types of labor ranging from hired labor (34.3%), family labor (30.8%) and the combination of hired labor and family labor (34.9%)

Table 2 shows that the age of the respondents was a significant factor affecting the farmers' income. Owing those younger farmers are more likely to employ the best waste management techniques which may lead to higher productivity and in-turn increase the income of the poultry farmers in the study area. The findings of this study are in line with findings of Afodu et al; (2019) in livelihood diversification and its determinants on rice farming households in Ogun State, Nigeria, they found that the negative sign in the age coefficient indicates that as the farm household grows older, the less diversified their livelihood.

Table 2: Factors Influencing Poultry Farmers Income in the Study Area

Variable	Coefficient	Standard Error	t- value
Constant	2.163***	0.522	4.144
Age	-0.821**	0.301	2.728
Sex	0.003	0.510	0.006
Marital Status	0.038	0.113	0.336
Household size	0.045*	0.026	1.731
Educational Status	0.069**	0.033	2.091
Farming experience	0.184	0.134	1.373
Production system	1.068**	0.418	2.555
Flock size	0.192***	0.044	4.364
Access to extension	1.004	0.681	1.474
Labor	-0.814**	0.361	2.255
Access to credit	0.681**	0.310	2.197
Quantity of waste	1.008***	0.291	3.464
Waste management technology	2.146***	0.630	3.406

The household size was found to be statistically significant and with a positive coefficient, showing that as household size increases, there is a high possibility of employing the best management techniques which may increase their farming income.

The coefficient of educational status of the farmers was found to be positive and significant at 5% level of probability which implies that the more the farmers are educated the more likely the best waste management techniques will be employed, this may increase the income of the poultry farmers in the study area. This is in line the findings of John et al. (2020), which says that the positive relationship between educational status and profit level of broiler farmers shows that farmers with higher educational status enjoy higher profit compared to their counterparts with lower educational status. This is also accordance with the work of Yunez-naude (2001) which opined that having some educational level of attainment facilitates entry into high paying jobs such as teaching, produce purchasing clerks, masters of transport stations, lottery vending as well as improving farmers understanding of farming practices and related issues.

The production system was also an important variable that determine the farmers' income. This implies that with a proper poultry farming system will increase the farmer's profit.

The flock size of the poultry farmers was highly significant (1%) with a positive coefficient. This implies that the farmer with larger flock size is more likely to received more income than their counter part with small size, this may due to the farmers taking economic of scale and also since the flock size is large, the farmers may have reasonable amount waste to process or sold directly to crop farmers.

The coefficient of labor used was negative but was statistically significant. This may imply that as the farmers spent more on the waste management technique the lesser their income.

Farmer access to credit is very vita in agricultural production. According to John et al; (2020), agricultural credit is crucial in improving agricultural productivity thereby enhancing the well-being of the farming households.

The quantity of waste produce was significant with a positive coefficient. This implies that the more the quantity of waste produced the higher the poultry farmers' income. This may be due to the fact that most of the poultry farmers in the study area sells the waste from their farms to crop farmers.

The regression result shows that the waste management techniques adopted by the poultry farmers was significant with a positive coefficient showing that farmers that adopted the techniques are more likely to have higher income than those that did not.

CONCLUSION

Waste is one of the laborious works in the poultry industry, but if properly managed can increase the profit of the farmers. From the results of they survey, the waste management techniques adopted by the poultry farmers was found to increase the income of the farmers. Production system is also a key factor on poultry waste management. An adoption of proper production system can also increase the income of the farmers. Extension agents should be trained on waste poultry management techniques to will improve the environment and also increase the income of the poultry farmers.

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ADVANCING ENVIRONMENTAL SUSTAINABILITY: STRATEGIES FOR INTEGRATING SCIENCE, TECHNOLOGY, AND CIRCULAR WASTE MANAGEMENT POLICIES IN DEVELOPING NATIONS

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ABSTRACT

This paper focused on exploring the key roles of environmental science and technology, with a particular interest on promoting green initiatives using Science, Technology and Innovation (STI) Policy and policy instruments in Africa. The work answered the call for integrating environmental concerns into development policies and proposed a model for integrating environmental management system into regional and national STI related policies to enhance environmental sustainability. The proposed model promotes synergy, collaboration and robust partnership between all the stakeholders for environmental sustainability. Additionally, the paper advocates for the promotion of technological innovation in urban, rural, and regional planning and management. The importance of fostering the development of a comprehensive national environmental database is emphasized, serving as a crucial support mechanism for sustainable economic development. This holistic exploration provides valuable insights for policymakers, researchers, and practitioners engaged in advancing circularity and environmental sustainability in developing nations. The proposal can aid the attainment of high standard of living, modern agriculture, blue economy and environmental sustainability as encapsulated in targets 2, 5, 6 and 7 of the Agenda 2063 respectively.

Key words: *STI Policy, Environmental Sustainability, Circular Waste Management*

INTRODUCTION

The National Science, Technology, and Innovation (STI) Policy in Nigeria has undergone significant evolution and revision to align with the country's developmental objectives and global agendas. The 2022 extant STI Policy from where this paper drew inspirations was crafted in coherence with the goals outlined in the Medium-Term National Development Plan (MTNDP) 2021-2025, the Nigeria Agenda 2050, the STI policy in Economic Community of West African States (ECOPOST), Agenda 2036, and the SDGs (Siyanbola, 2022). While the policy aims to leverage STI to foster the growth of a robust, diversified, and sustainable economy, it enshrined environmental sustainability in waste management. The standard of living for Nigerian citizens amongst other strategic areas of the policy (FGN, 2022).

In line with the objectives of the Nigeria STI policy, there is a clear emphasis on integrating environmental considerations into all aspects of development policies. This includes promoting public awareness of the scientific principles underlying environmental actions and advocating for the development of effective waste management systems to mitigate pollution emissions from waste generation. This ideology resonates with the ECOWAS Environmental Policy (2008). It equally aligns with the broader agenda of advancing environmental sustainability and circular waste management practices not only within Nigeria but also across selected African countries, such as Egypt, South Africa, Rwanda and others outlined in African Agenda 2063 (Romero-Hernández, et al, 2018; Belemsobgo, 2022)

Globally, efforts are needed to achieve environmental sustainability (Tennakoon & Kulatunga, 2021) especially in underdeveloped nations where the effects of environmental deterioration are frequently most felt. The combination of science, technology, and circular waste management strategies has shown promise in recent years as a means of addressing environmental issues and promoting social and economic advancement, (Hammed, et.al, 2021, Zia, et.al, 2023). The necessity of promoting green projects and incorporating environmental considerations into development policies is becoming more widely acknowledged as the effects of human activity on the environment become more apparent (Fan, et.al, 2019; Behera, 2023).

Previous efforts were directed towards development of sustainability plans, standalone policies and advocacy for stakeholders to network in functionalization of the circular economy in Africa. There are deficits in provision of functional frameworks that integrates regional and member states STI policy with environmental sustainability. This paper seeks to explore the important field of environmental science and technology, emphasizing sustainable practices, green initiatives, and circular waste management within the framework of Nigeria extant STI policy (FGN, 2022). By examining the convergence of science, technology, and environmental sustainability, this study aims to offer significant perspectives to practitioners, researchers, and policy makers within the STI environmental conservation initiatives, particularly in developing countries. We developed a model for effective circular waste management policies for Africa using the Nigeria STI policy as a guide.

The Nigeria STI Policy on Circular Waste Management and Environmental Sustainability

The Nigeria STI policy was explicit on the need to promote the integration of environmental concerns in all development policies and ensuring public understanding of the scientific basis of their actions on the environment. This was further strengthened with the policy directives on the need to develop appropriate and effective waste management system to reduce pollution emission from waste generation in Nigeria. The innovation focused policy equally encouraged the STI stakeholders to develop mitigating and adaptive technologies on climate change. The aim was to promote innovative technologies towards planning and management of urban, rural and regional wastes in Nigeria. While emphasizing the pivotal roles of capacity building in the advancement of environmental sustainability, Nigeria explicitly aspired to monitor, predict and mitigate adverse effects of man-made and natural phenomena on her environment. The prediction of floods, deforestation, drought and desertification and all forms of erosion would enable effective management.

One of the key drivers of policy implementation is funding. The Nigerian 2022 STI policy proposed the integration of environmental factors with standard national accounts/assets to improve environmental monitoring systems. The policy which was based on the National Innovation System (NIS) envisioned that a sustainable environmental management system should be based on database. Hence, the policy advised that a national environmental database should be established and maintained for sustainable economic development (FGN, 2022).

Rationale for Framework

This paper embraced the qualitative method of research by developing a conceptual framework to model the interactions between the stakeholders in waste management. Consideration was given to the government agencies, local authorities, waste management industry experts and even the environmental NGOs. The interactions between these stakeholders was hinged on the national systems of waste management. The system attracts relevant stakeholders like the Higher Education and Research Institutions (HERIs) which are pivotal to the design and operations of a sustainable waste management through research, education, and training programs. The model incorporates the consumers, local authorities, civil society and households. The rationale was to ensure those who generate waste can play a crucial role in waste reduction, segregation, and recycling efforts through responsible consumption and disposal practices.

Novel Model for Advancing Environmental Sustainability

Globally, environmental sustainability is a pressing issue (Smith, 2020) particularly in developing nations where challenges related to waste management and resource utilization are prevalent. This model proposed and presented in figure 1 is a novel model aimed at advancing environmental sustainability in Africa, using the ECOWAS as a case through the integration of STI with circular waste management policies. This framework gained strength from the ECOWAS Environmental Policy and environmental component of the ECOWAS STI Policy (the ECOPOST). Dovetailed to Nigeria, by focusing on sustainable waste management within the context of the STI policy. The model can support the attainment of the second plan of Agenda 2063, particularly goals 1, 5, 6, and 7, which emphasize the high standard and quality of living, modern agriculture, blue ocean economy, and sustainable environment, respectively (Ndizera & Muzee, 2018).

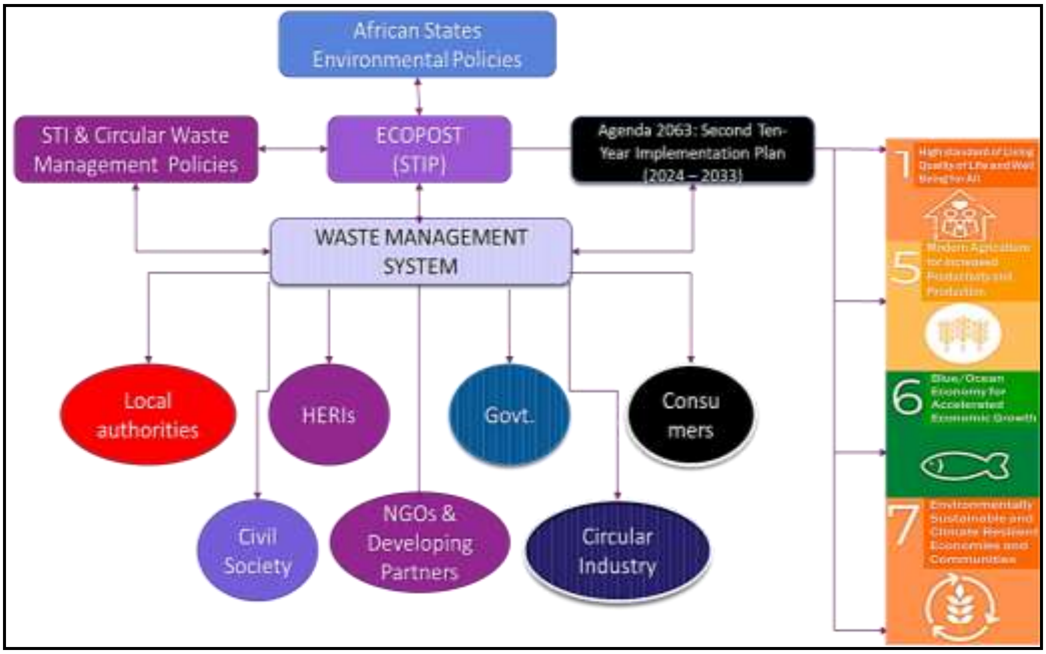

Figure 1: Analytical Framework for Advancing Environmental Sustainability (Authors' Idea)

Existing literature highlights the importance of integrating STI with waste management policies to promote environmental sustainability. Studies have shown that effective waste management practices, coupled with technological innovations, can mitigate environmental degradation and promote resource efficiency (Smith, 2020). The ECOWAS Environmental Policy and ECOPOST provide a framework for addressing environmental challenges in the West African region, including waste management. This model gives a better coordination approach to the attainment of the aspirations of regional and local STI and environmental policies.

In addition, this proposed model comprises several interconnected components which promotes for the alignment of national STI policies with circular waste management policies, leveraging frameworks such as ECOPOST to promote coherence and synergy. The need for development and adoption of innovative technologies for waste collection, segregation, recycling, and resource recovery was anticipated by considering the circular industry as stakeholders. The model resonates with the Nigerian STI policy on capacity building while fostering human capital development and institutional capacity building to support the implementation of integrated STI and waste management policies.

Through public engagement with civic societies and advocate groups, the model delegates local authorities and all stakeholders to be part of the waste management system. This will deliver a participatory waste reduction, reuse, and recycling initiatives as education and outreach programs are expected to be designed by the NGOs in collaboration with developing partners.

Implications of the model for development agenda

The proposed model offers a comprehensive approach to addressing environmental sustainability challenges in developing nations. By integrating STI with circular waste management policies, the model harnesses the potential of technological innovation to optimize resource utilization, reduce pollution, and promote sustainable development. Moreover, the model aligns with the objectives of Agenda 2063, particularly goals 1, 5, 6, and 7, by addressing key priorities such as improving living standards, enhancing agricultural productivity, fostering a blue ocean economy, and ensuring a sustainable environment.

CONCLUSION

The proposed model represents a promising approach to advancing environmental sustainability in developing nations using STI policy approach. By leveraging the synergies between STI and circular waste management policies, the model offers a pathway towards achieving selected development goals outlined in Agenda 2063. However, successful implementation will require strong political commitment, institutional coordination, and stakeholder engagement at regional, states and local government levels.

Apparently, there is a lot of potential for improving environmental sustainability in developing countries through the combination of science, technology, and circular waste management strategies. Through the utilization of scientific innovation, technical innovation, and the application of circular economy principles, Africa nations may proficiently tackle environmental issues and promote sustainable development.

To build resilience to environmental risks and achieve sustainable economic growth, it is imperative to establish efficient waste management systems, deploy mitigating and adaptive technologies, and integrate environmental factors into national STI eco system. But significant progress will need multi-stakeholder cooperation at the national and international levels, strong political will, and solid policy frameworks. If they work together, developing countries can set the path for future generations to have a more resilient and sustainable future. Thus we recommend;

i. Africa needs to invest in research and development to identify innovative waste management technologies tailored to African contexts.
ii. Member states must enhance technical skills and expertise in waste management through training programs, workshops, and educational initiatives.
iii. Develop comprehensive waste management policies and regulations that prioritize sustainability, environmental protection, and public health.

iv. Facilitate the transfer of proven waste management technologies, involve all stakeholders and engage in public-private partnership to drive the circular economy.

v. Embrace a circular economy approach that prioritizes waste reduction, reuse, and recycling.

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