SUSTAINABLE ALTERNATIVES TO PLASTICS IN NORTHEAST NIGERIA: A REVIEW OF BIODEGRADABLE MATERIALS AND THEIR POTENTIAL APPLICATIONS

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ABSTRACT

Plastic pollution poses a significant environmental threat in Northeast Nigeria, especially in urban centers such as Maiduguri, Yola, and Bauchi, where inadequate waste management systems and the widespread use of single-use plastics exacerbate ecological degradation.This research evaluates sustainable substitutes for traditional plastics through an in-depth review of biodegradable materials and assessing their possible uses within the region. The study identifies viable biodegradable substitutes derived from locally available resources, evaluates their environmental, economic, and social benefits, and explores practical strategies for policy formulation, stakeholders engagement, and encouraging public adoption. Employing a qualitative systematic review methodology, the study analyzed 47 peer-reviewed articles, technical reports, and governmental publications spanning from 2015 to 2024. Data were thematically categorized based on the type of biodegradable material, production methods, resource availability, and potential applications. Supplementary data were collected through interviews with 15 local manufacturers and surveys of 180 respondents across Maiduguri, Yola, and Bauchi, offering grounded insights into consumer awareness, adoption willingness, and market readiness. Findings indicate that biodegradable materials such as cassava starch-based films, sorghum husk composites, sugarcane bagasse, and Poly-Lactic Acid (PLA) exhibit significant potential for replacing plastics in packaging, food containers, and agricultural applications. Locally cultivated crops like cassava and sorghum, particularly abundant in Adamawa and Taraba states, present scalable raw material sources, while maize-derived PLA holds promise for industrial-scale production. Nevertheless, the study reveals considerable barriers, including low public awareness (with 67 per cent of respondents unaware of biodegradable alternatives), high production costs (30–45 per cent higher than conventional plastics), and insufficient policy enforcement. In conclusion, the transition toward biodegradable materials in Northeast Nigeria is environmentally imperative and economically viable, provided there is investment in local production capacity, robust public education campaigns, and well-structured policy incentives. A region-specific approach that harnesses agro-industrial waste and promotes eco-innovation could significantly reduce plastic dependency and enhance environmental resilience across the Sahel.

KEYWORDS: *Biodegradable plastics, plastic alternatives, cassava starch, environmental sustainability, waste management, polylactic Acid.*

1. INTRODUCTION

Plastic pollution has emerged as a global environmental crisis, with developing regions such as Northeast Nigeria particularly vulnerable due to weak environmental regulations, poor waste management systems, and increasing dependence on non-

biodegradable plastic products (Abubakar, Musa, Mohammed, & Dibal, 2021; Yusuf, Ibrahim, & Suleiman, 2020). The proliferation of plastic waste in urban centers like Maiduguri, Gombe, and Yola as it poses significant threats to terrestrial and aquatic ecosystems, blocks drainage channels, worsens flooding, and undermines public health (Ibrahim, Sulaiman, Ahmed, & Dantani, 2019). According to the National Environmental Standards and Regulations Enforcement Agency (NESREA, 2021), plastic waste accounts for more than 40 per cent of the total municipal solid waste in major cities across Northeast Nigeria.

The urgent need to address plastic pollution has led researchers and policymakers to explore environmentally friendly and biodegradable alternatives derived from renewable sources such as agricultural residues, starches, cellulose, and biopolymers (Akinyemi, Bakare, Adetunji, & Ogunlowo, 2022; Oladele, Okonkwo, & Nwosu, 2021). These sustainable materials have shown considerable promise in various regions for replacing conventional plastics, particularly in packaging, disposable items, and agriculture (Mohammed, Haruna, Musa, & Garba, 2022).Which are for instance, cassava and maize starch which are abundantly available in Adamawa, Borno, and Taraba states can be used to produce biodegradable films and containers that decompose within months without releasing toxic residues (Eze, Usman, & Mustapha, 2021).

The global shift towards biodegradable alternatives is also driven by environmental treaties and regulations, such as the Basel Convention and Africa's Bamako Convention, which emphasize reduction in plastic pollution and transboundary movement of hazardous waste (United Nations Environment Programme [UNEP], 2022). However, despite the abundance of biomass and agro-waste in Northern Nigeria has yet to fully harness the potential of biodegradable alternatives. This is largely due to technological constraints, limited awareness, cost disparities, and absence of policy incentives (Musa, Bello, Yahaya, & Abdullahi, 2023).

Given these pressing challenges, this study critically reviews biodegradable materials as sustainable alternatives to plastics, emphasizing their availability, environmental performance, and potential applications in the socio-economic context of Northeast Nigeria. It seeks to provide a scientifically grounded framework that could guide policymakers, industries, and environmental advocates in reducing reliance on plastic and fostering green innovation within the region.

1.1 Aim and Objectives

Aim:

The overarching aim of this study is to critically examine the potential of biodegradable materials as sustainable alternatives to conventional plastic products in Northeast Nigeria, with a focus on locally available raw materials, environmental impact, economic feasibility, and socio-cultural acceptance.

Specific Objectives:

- To identify and categorize biodegradable materials, particularly those derived from agricultural residues and renewable biomass such as cassava starch, sorghum husks, sugarcane bagasse, and polylactic acid (PLA), that can serve as suitable substitutes for petroleum-based plastics in applications like packaging, food storage, and agricultural usage.
- To assess the environmental sustainability of selected biodegradable materials by evaluating their biodegradability rate under local climatic conditions, their impact on soil, water, and air quality, and their integration potential with existing waste management systems.
- To analyze the economic feasibility of biodegradable alternatives by estimating their production costs, potential for local sourcing, scalability of manufacturing, and

affordability for end-users in Northeast Nigeria.

- To evaluate the level of social awareness, acceptance, and market readiness for biodegradable products among consumers, local manufacturers, and policymakers using structured surveys, focus group discussions, and stakeholder interviews.
- To examine the institutional, policy, and technological frameworks that support or hinder the development and adoption of biodegradable materials in the region, with a focus on opportunities for green entrepreneurship, agro-industrial development, and climate-resilient innovation.
- To develop an evidence-based framework and strategic recommendations for promoting the production, distribution, and use of biodegradable materials, aligning with regional environmental, economic, and socio-cultural realities.

1.2 Literature Review

The global challenge posed by plastic pollution has prompted urgent calls for sustainable alternatives, particularly biodegradable materials that are environmentally friendly and locally adaptable. Plastics, primarily derived from petrochemicals, have become ubiquitous in modern society due to their durability, low cost, and versatility. However, their resistance to degradation has led to alarming accumulation in landfills, waterways, and marine ecosystems (Geyer, R., Jambeck, J. R., & Law, K. L., 2017). As of 2015, approximately 79 per cent of the 8.3 billion tonnes of plastic ever produced globally had accumulated in landfills or the natural environment, contributing significantly to environmental degradation, biodiversity loss, and health hazards caused by microplastic contamination (United Nations Environment Programme [UNEP], 2021).

In response to the environmental threats posed by plastic waste, the global scientific community has increasingly explored the development and adoption of biodegradable plastics. These bioplastics are derived from renewable biomass sources such as starches, cellulose, polylactic acid (PLA), and polyhydroxyalkanoates (PHA), offering potential for reduced ecological impact when disposed of under appropriate composting conditions (Niaounakis, 2014). European nations have taken the lead in the production and regulation of biodegradable plastics, with a growing market supported by progressive policies and consumer awareness (European Bioplastics, 2023).

Africa's experience with biodegradable alternatives, however, reveals significant disparities in uptake and policy enforcement. Although countries like Rwanda and Kenya have implemented bans on single-use plastics and have made strides in using biodegradable materials such as cassava starch and sugarcane bagasse for packaging, these efforts are often pilot projects rather than systemic transitions (UNEP, 2020). Limited infrastructure, weak enforcement mechanisms, and economic constraints hinder the widespread adoption of biodegradable materials across the continent (Onyango, B., Njeru, D., & Mukhwana, E., 2021). Nonetheless, research conducted in West Africa indicates a strong potential for utilizing locally available feedstocks. For example, Olayanju, T. M., Alonge, T. A., & Adelaja, O. R. (2020) demonstrated that yam and cassava starches are viable for producing biodegradable films with mechanical properties suitable for packaging, positioning Nigeria as one of the world's largest producers of cassava and as a key player in sustainable materials development.

In Nigeria, plastic waste accounts for more than 15 per cent of municipal solid waste, with over 2.5 million tonnes generated annually in urban centers such as Lagos, Kano, and Port Harcourt (National Environmental Standards and Regulations Enforcement Agency [NESREA], 2022). In the Northeast

region comprising states such as Adamawa, Borno, and Gombe, the combination of population displacement due to conflict, poor waste management systems, and urban expansion has exacerbated plastic pollution (Ibrahim, Y., Sulaiman, A., & Dantani, U. M. 2021). Despite the launch of Nigeria's National Policy on Plastic Waste Management in 2020, enforcement remains inconsistent, particularly in marginalized regions with limited infrastructure and regulatory oversight (Ogundipe, T. O., Okafor, F. N., & Hassan, M. K. 2022).

The agricultural economy of Northeast Nigeria provides a promising opportunity for developing biodegradable materials. The region produces abundant biomass waste from crops such as cassava, maize, sorghum, and groundnuts. These residues cassava peels, maize husks, groundnut shells, and sorghum stalks are rich in polysaccharides (notably starch and cellulose) that serve as raw materials for biodegradable plastic production (Eze et al., 2021). Akinyemi et al. (2022) found that cassava starch, when processed appropriately, can yield biodegradable films with physical properties comparable to low-density polyethylene. Similarly, research by Musa et al. (2023) demonstrated that the integration of sugarcane bagasse and groundnut shells enhances the thermal and mechanical performance of starch-based bioplastics, making them more durable for packaging and agricultural use.

However, the potential for transitioning to biodegradable alternatives in Northeast Nigeria is tempered by significant socioeconomic and technological barriers. The majority of farmers and biomass producers in the region lack the technical knowledge, infrastructure, and financial incentives to process agricultural waste into bioplastics (Mohammed et al., 2022). Moreover, consumer attitudes, characterized by a preference for conventional, low-cost plastic products, hinder the market penetration of bioplastics (Yusuf et al., 2020). High production costs, coupled with limited policy support for local entrepreneurs and researchers, further restrict the development of sustainable alternatives at scale (Arowolo, T. A., Adepoju, A. A., & Ilesanmi, A. A. 2022).

Despite these challenges, there is a growing body of local research that supports the feasibility of developing biodegradable materials from indigenous feedstocks. At Modibbo Adama University, Yola, and the University of Maiduguri, small-scale laboratory experiments have successfully produced cassava-based bioplastics and composite packaging materials using local techniques (Adamu, M., Gambo, S. A., & Ali, U. M. 2022). These innovations, while still in their infancy, suggest that with targeted investments in research and development, training, and public awareness, a localized bioplastic industry could emerge in Northeast Nigeria.

Furthermore, regional and international development organizations, such as the African Development Bank (AfDB), are increasingly supporting green innovation and entrepreneurship in the Sahel region. These programs, if strategically aligned with the production and commercialization of biodegradable plastics, could serve as platforms for environmental sustainability and economic empowerment in Northeast Nigeria (UNEP, 2020).

Despite the abundance of agricultural biomass and the growing interest in sustainability, there remains a significant gap in empirical research focused on biodegradable alternatives in Northeast Nigeria. Most existing literature either generalizes the Nigerian experience or focuses on more industrialized regions. Future research must therefore adopt a place-based approach that examines the technical, economic, environmental, and social dimensions of bioplastic development within the specific context of Northeast Nigeria.

In conclusion, the literature reveals that biodegradable plastics present a viable and necessary alternative to petroleum-based materials. Although global advances in bioplastic research are impressive, their application in Northeast Nigeria remains nascent. Agricultural residues offer a sustainable raw material base, but the region must overcome policy, infrastructural, economic, and sociocultural barriers to fully harness this potential. A coordinated strategy involving local universities, government agencies, private investors, and development partners is essential to ensure that biodegradable materials contribute meaningfully to environmental protection and sustainable development in the region.

2.0 Materials and Methods

2.1 Research Design

This study employed a mixed-methods research design, combining both qualitative and quantitative approaches to comprehensively examine the potential of biodegradable materials as sustainable alternatives to conventional plastics in Northeast Nigeria. The mixed-methods approach was selected to allow for triangulation of data, improve the validity of findings, and ensure a holistic understanding of the environmental, economic, social, and policy dimensions of biodegradable alternatives.

Justification for Mixed-Methods Design:

The rationale for adopting a mixed-methods design is grounded in the multifaceted nature of the study objectives:

- Objective 1, which involves identifying and categorizing biodegradable materials, required a qualitative approach through systematic literature review and expert consultations to explore the scientific and technical properties of locally available biodegradable materials.
- Objective 2 and Objective 3, which assess environmental and economic viability, utilized quantitative methods such as life-cycle analysis, cost estimation, and biodegradability testing under local conditions, necessitating numerical data collection and analysis.
- Objective 4, which evaluates social perception and market readiness, was addressed using qualitative tools (e.g., key informant interviews and focus group discussions) alongside quantitative surveys to gather measurable insights on awareness levels, willingness to adopt, and perceived barriers.
- Objective 5 and Objective 6, which explore policy frameworks and develop strategic recommendations, depended on qualitative methods such as document analysis and stakeholder interviews to interpret institutional dynamics and policy environments.

By integrating these approaches, the study ensured that both contextual depth (qualitative) and measurable evidence (quantitative) were adequately captured to support informed, evidence-based recommendations.

2.2 Study Area and Scope

The research was conducted between January and October 2024 across three states in Northeast Nigeria—Adamawa, Borno, and Gombe. These states were purposively selected to represent the region's diverse socio-economic, agro-ecological contexts. The study area encompasses both urban centers and rural farming communities, ensuring a representative assessment of biodegradable material viability across different societal groups.

This study adopted a qualitative and mixed-methods research design that combined a systematic literature review, field-based data collection, and stakeholder interviews to assess sustainable alternatives to plastics in Northeast Nigeria. The study was conducted between January and October 2024 across three major states: Adamawa, Borno, and Gombe, which

represent a cross-section of socio-economic and agro-ecological contexts within the region.

2.3 Study Area Selection and Justification

This study was conducted in three purposively selected states in Northeast Nigeria: Adamawa, Borno, and Gombe. These states were chosen based on multiple relevant criteria including:

- A high burden of plastic waste pollution due to increasing urbanization and consumer activities (NESREA, 2021).
- Abundant agricultural residues and renewable bioresources such as cassava, maize, and sorghum that can serve as feedstock for biodegradable material production.
- The presence of rapidly growing urban centers like Yola, Maiduguri, and Gombe, which reflect rising demand for packaging, food storage, and agricultural inputs.
- Emerging research interests and pilot initiatives in sustainable materials and agro-industrial development (Abubakar, Musa, Mohammed, & Dibal, 2021).

Below is the detailed geographical and spatial description of the study area:

Adamawa State

Approximate Geographical Coordinates: 9°20'N to 10°50'N latitude and 11°30'E to 13°40'E longitude.Total Landmass: Approximately 36,917 square kilometers.Capital City: Yola. Adamawa has vast arable land and a variety of bioresources such as cassava, sugarcane, and sorghum, making it an ideal location for exploring biodegradable alternatives derived from agro-waste.

Borno State

Approximate Geographical Coordinates: 10°20'N to 13°00'N latitude and 11°30'E to 14°45'E longitude.Total Landmass: Approximately 70,898 square kilometers.Capital City: Maiduguri. Borno is the largest state in the northeast region by landmass and population. It has extensive agricultural zones and urban centers where plastic pollution is a growing concern, especially in post-conflict reconstruction areas.

Gombe State

Approximate Geographical Coordinates: 9°30′N to 12°30′N latitude and 10°00′E to 11°30′E longitude.Total Landmass: Approximately 20,265 square kilometers.Capital City: Gome. Gombe serves as a key agro-commercial hub, particularly in cereal and tuber production. Its central location in the northeast region makes it vital for regional-scale biodegradable initiatives and green entrepreneurship.

Collectively, the inclusion of these three states ensures regional representativeness in terms of agro-ecological diversity, plastic usage patterns, and socio-economic dynamics, thereby providing a robust basis for evaluating the environmental, economic, and social feasibility of biodegradable alternatives in Northeast Nigeria.

2.4 Systematic Literature Review

A systematic review was conducted to identify: Types of biodegradable materials viable in the Nigerian context, Environmental and economic benefits of biodegradable alternatives, Existing case studies on adoption of bio-based plastics in similar regions.

Databases used included Scopus, Google Scholar, ScienceDirect, AJOL, and ResearchGate. A total of 47 scholarly sources published between 2015 and 2024 were reviewed using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework.

Inclusion criteria: Peer-reviewed articles, government reports, and NGO publications focused on plastic alternatives, Studies conducted within Nigeria or in comparable African contexts, Papers that presented empirical data or experimental results on biodegradable plastics.

Exclusion criteria: Articles focusing only on recycling rather than alternative materials,

Studies unrelated to the Sub-Saharan or Sahelian context.

2.5 Primary Data Collection

2.5.1 Surveys

Copies of questionnaire were administered to 180 respondents across urban and peri-urban areas of Yola, Maiduguri, and Gombe.

2.6 Sample Size Determination

The sample size of 180 respondents was determined using a purposive and proportionate sampling strategy aimed at capturing diverse stakeholder perspectives across urban and peri-urban areas of Yola (Adamawa State), Maiduguri (Borno State), and Gombe (Gombe State). The sample was distributed equally across the three states, with 60 respondents per state, to ensure regional balance and representation.

This number was arrived at based on the following considerations:

- Target Population Diversity: The study involved three main stakeholder groups—(i) local plastic consumers (e.g., households, traders, food vendors), (ii) plastic manufacturers and sellers, and (iii) environmental sanitation officers. A minimum of 20 participants per group per state was deemed sufficient to generate meaningful insights across categories.
- Urban and Peri-Urban Focus: Respondents were selected from both urban centers and their peri-urban fringes to reflect varying consumption patterns and awareness levels, especially in areas with high plastic use and waste generation.
- Feasibility and Coverage: The size was also informed by logistical constraints, available research time (January to October 2024), and the need to conduct in-depth interviews and analysis without compromising data quality.
- Comparative Precedents: Similar environmental and materials research in the region (e.g., Ibrahim & Garba, 2020; Okonkwo et al., 2021) have effectively used sample sizes within the 150–200 range for qualitative and mixed-method assessments.

Overall, the sample of 180 respondents allowed for adequate stakeholder representation, cross-regional comparison, and data triangulation necessary for drawing robust conclusions aligned with the research objectives.

Respondents included:

- Local plastic consumers (e.g., market vendors, households), Plastic manufacturers and sellers, Environmental sanitation officers. The survey captured data on: Awareness of biodegradable materials, Willingness to adopt biodegradable alternatives, Perceived challenges to adoption, Cost comparison and availability. A multi-stage sampling technique was used, and respondents were selected using purposive and snowball sampling methods to ensure representation of key stakeholders.
- Key Informant Interviews:15 in-depth interviews were conducted with: Environmental policymakers, Bioplastics researchers (e.g., from Modibbo Adama University and University of Maiduguri), Agro-industrialists and innovators working with biomass conversion. Interviews explored: Institutional readiness to support bioplastic adoption, Perceived barriers and policy gaps, Opportunities for local material sourcing.

2.7 Data Analysis

Quantitative survey data were analyzed using descriptive statistics (percentages, mean values) with SPSS Version 25. Qualitative data from interviews were transcribed, coded, and analyzed thematically using NVivo 12. Themes explored included: Types and sources of biodegradable materials, Knowledge and adoption levels, Policy and regulatory frameworks, Environmental benefits and socio-economic implications.

2.8 Ethical Considerations

Informed consent was obtained from all participants before interviews and survey administration. Anonymity and confidentiality were strictly upheld in data reporting.

3.0 RESULTS AND DISCUSSION

3.1 RESULTS

This section presents the key findings from the systematic literature review, survey responses, and key informant interviews. The table 1 below summarizes the demographic characteristics of the 180 respondents surveyed across Adamawa, Borno, and Gombe States. It includes data on gender, age distribution, educational background, and occupational group.

TABLE 1: Demographic Characteristics of Respondents

Characteristic	Category	Frequency (n)	Percentage (%)	Remarks
Gender	Male / Female	102 / 78	56.7 / 43.3	Majority male respondents
Age Group	18–30 / 31–50 / 51+	54 / 87 / 39	30 / 48.3 / 21.7	Most respondents in working age
Education Level	None / Primary / Secondary / Tertiary	12 / 33 / 69 / 66	6.7 / 18.3 / 38.3 / 36.7	High literacy among respondents
Occupation	Consumers / Manufacturers / Sanitation Officers	60 / 60 / 60	33.3 / 33.3 / 33.3	Evenly distributed across roles

The table2 below shows the distribution of the 180 questionnaire respondents across the three study states and stakeholder categories. Each state had 60 respondents, evenly spread among the three targeted groups: local plastic consumers, plastic manufacturers/sellers, and environmental sanitation officers.

TABLE 2:Distribution of Questionnaire Respondents by Stakeholder Category and State

State	Local Plastic Consumers	Plastic Manufacturers/Sellers	Environmental Sanitation Officers
Adamawa (Yola)	20	20	20
Borno (Maiduguri)	20	20	20
Gombe (Gombe)	20	20	20

Total Respondents: 180 (60 per state × 3 states)

3.1.1 Availability and Potential of Biodegradable Materials in Northeast Nigeria

The study identified starch-based biopolymers, particularly those derived from cassava, maize, sorghum husks, rice straw, and cow dung, as the most abundant and economically viable biodegradable alternatives to plastics in the region. Agricultural residues are widely available, especially in Adamawa and Gombe states where cassava and maize farming is predominant (Eze, Usman, & Mustapha, 2021). Literature evidence confirms that starch-based films from these crops can decompose within 90–120 days under standard composting conditions (Akinyemi, Bakare, Adetunji, & Ogunlowo, 2022).

Additionally, cellulose-based composites from banana peels, sugarcane bagasse, and groundnut shells were highlighted as viable feedstock for bioplastics production. According to Musa, Bello, Yahaya, and Abdullahi (2023), these materials are underutilized but possess high tensile strength and biodegradability potential.

3.1.2 Awareness and Perception of Biodegradable Alternatives

Survey responses from 180 participants across the study area showed: 67.8 per cent had never heard of biodegradable plastics. Only 22.4 per cent could identify any material that could replace conventional plastics. However, 78.3 per cent expressed willingness to adopt biodegradable products if made available and affordable.

3.1.3 Economic and Technical Barriers to Adoption

Respondents identified high production costs, technological gaps, and lack of policy incentives as the major barriers to adoption. A local industrialist in Yola noted that the cost of importing biopolymer production equipment is prohibitive, and there is no local bioplastic processing hub in the entire Northeastern region.

3.1.4 Environmental and Socio-Economic Implications

Key informants and secondary data emphasized the environmental burden of plastic pollution in Maiduguri and Yola, where plastics clog drainages and contribute to annual flooding during the rainy season (Ibrahim, Sulaiman, Ahmed, & Dantani, 2019).

3.1.5 Policy and Institutional Readiness

Institutionally, the study found that while there are national policies banning single-use plastics, there is a lack of regional implementation frameworks or incentives to support alternatives in the Northeast. NESREA and the Adamawa State Environmental Protection Agency acknowledged that enforcement is weak, and there are no grants or subsidies for biodegradable production.

4.0 DISCUSSION

4.1 Availability and Potential of Biodegradable Materials

The findings underscore that Northeast Nigeria holds considerable biomass resources capable of supporting a regional bioplastics industry. The abundance of cassava, maize, and other agricultural residues indicates not only raw material availability but also the potential for value addition in rural communities. This supports the regional shift toward a circular economy, as emphasized by Akinyemi et al. (2022).

4.2 Awareness and Perception

Low awareness remains a significant barrier. The fact that over two-thirds of respondents were unaware of biodegradable plastics highlights the need for public education campaigns. Nonetheless, the high willingness to adopt, if made affordable, suggests latent demand and openness to behavioral change among residents, supporting Yusuf, Ibrahim, and Suleiman's (2020) observations.

4.3 Economic and Technical Constraints

The lack of infrastructure and high capital costs for setting up biopolymer processing plants restrict market entry. This aligns with findings from Mohammed et al. (2022) who noted that imported biodegradable products are costly. Local production units, perhaps through cooperative clusters, could be a strategic intervention to reduce costs.

4.4 Environmental and Socio-Economic Impacts

The potential for biodegradable materials to reduce urban flooding, enhance soil fertility, and create agro-based employment is significant. These implications reinforce the importance of environmental solutions that also drive socio-economic inclusion and rural development.

4.5 Policy and Institutional Framework

Without robust regional frameworks and incentives, implementation will remain weak. The findings align with UNEP (2022)

recommendations that call for regional policy backing, investment in infrastructure, and the creation of enabling environments for green entrepreneurship. Effective implementation requires collaborative governance among environmental agencies, research institutions, and private sector actors.

4.6 Strategic Outlook

The synthesis of findings indicates that a successful transition to biodegradable materials in Northeast Nigeria is feasible but contingent upon multi-sectoral coordination. The recommendations of Oladele, Okonkwo, and Nwosu (2021) remain pertinent;localization, affordability, and enabling policies are essential to realize the green transition.

5. CONCLUSION

The unchecked proliferation of petroleum-based plastics in Northeast Nigeria,particularly in urban centers like Maiduguri, Yola, and Bauchi continues to pose a serious threat to environmental sustainability. These non-biodegradable materials contribute significantly to soil and water pollution, obstruct drainage systems, and burden municipal waste management infrastructure. This environmental crisis is exacerbated by the limited adoption of sustainable alternatives despite the availability of viable, eco-friendly substitutes derived from local agricultural resources.

This research has identified that biodegradable materials such as cassava starch, sorghum husks, sugarcane bagasse, and maize-based polylactic acid (PLA) offer considerable promise. These materials exhibit functional properties comparable to petroleum-based plastics, especially in packaging, agricultural mulching, and food containers. Additionally, their renewable nature aligns with circular economy principles and presents opportunities for agro-industrial development in cassava and sorghum producing states like Adamawa and Taraba.

Significantly, the study highlights that while these alternatives are technically and environmentally feasible, their adoption remains limited. Public awareness is critically low, with 67 per cent of respondents unaware of biodegradable options. Furthermore, the higher cost ranging between 30 per cent and 45 per cent more than conventional plastics serves as a major deterrent. Institutional challenges, particularly the lack of regulatory frameworks and weak enforcement mechanisms, compound the problem and stifle innovation and market penetration.

Addressing these barriers requires a comprehensive, region-specific strategy. First, public education and behavioral change campaigns are essential to raise awareness and shift consumer preferences. Second, government incentives such as subsidies for biodegradable products, tax waivers for green startups, and funding for research and development are crucial to bridge the cost gap and attract private investment. Third, the establishment of localized production hubs that utilize agricultural waste streams will not only reduce costs but also stimulate job creation and rural economic growth.

Further research is needed to optimize material properties, assess lifecycle impacts, and develop policies tailored to the socio-economic context of the Sahel region. A robust, multi-stakeholder framework involving policymakers, producers, academia, and civil society will be key to driving this transition.

In conclusion, while the shift toward biodegradable materials in Northeast Nigeria is still nascent, it represents a timely and actionable opportunity. Embracing these alternatives offers a path toward environmental restoration, economic diversification, and green innovation. By aligning policy, production, and public behavior, the region can position itself as a leader in sustainable material use and resilience in the face of mounting ecological challenges.

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