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Assessment of constraints affecting the adoption and implementation of biogas-based farming systems in Taraba State, Nigeria

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Abstract

This study assessed the constraints affecting the adoption and implementation of biogas-based farming systems (BBFS) in Taraba State, Nigeria. The specific objectives were to describe the socio-economic characteristics of the farmers and to identify the key constraints to BBFS adoption. Using a multi-stage sampling technique, primary data were collected from 346 farmers via structured questionnaires. Descriptive statistics and a 5-point Likert scale were employed for analysis. Results revealed that the typical farmer is male, middle-aged, experienced, and operates a small-scale farm. The analysis of constraints identified the most critical barriers. The foremost was a severe lack of access to credit or loans (mean=4.46), followed by the high cost of installation (mean=3.80), insufficient government or NGO support (mean=3.79), and inadequate technical knowledge within communities (mean=3.68). Conversely, cultural beliefs, general awareness, and maintenance access were not primary impediments. The study concludes that financial and institutional bottlenecks are the primary obstacles. Recommendations include establishing targeted credit schemes, strengthening technical extension services, and fostering local supply chains to unlock the potential of biogas for sustainable energy and agriculture in Taraba State.

Keywords: Constraints; Adoption; Implementation; Biogas-based; Farming Systems; Taraba State; Nigeria

1. Introduction

Nigeria, with its population exceeding 220 million, is confronted by a deepening nexus of energy poverty, environmental stress, and agricultural stagnation. The agricultural sector, which employs a large portion of the populace and contributes significantly to the nation's GDP, is predominantly sustained by smallholder farmers who face escalating challenges. These include declining soil fertility, the prohibitive cost of synthetic fertilizers and fuel, and the increasing unpredictability of climate patterns (World Bank, 2023). Concurrently, the nation suffers from a severe energy deficit, with a vast percentage of the population, particularly in rural areas, lacking access to reliable electricity and depending on firewood and charcoal for cooking. This reliance accelerates deforestation and poses severe public health risks through indoor air pollution (IEA, 2022).

Within this context, biogas-based farming systems (BBFS) offer a transformative, circular model that directly addresses these interconnected crises. This integrated approach involves the anaerobic digestion of readily available organic waste such as livestock manure, crop residues, and food waste to produce two valuable outputs: biogas for clean, renewable energy and nutrient-rich digestate for organic soil amendment. The technology promises a multi-pronged solution: enhancing energy access, improving soil health and crop yields, mitigating greenhouse gas emissions, and promoting sustainable waste management. Recent assessments highlight the substantial potential, suggesting that Nigeria's livestock sector alone could generate over 25 billion cubic meters of biogas annually, underscoring a significant untapped resource (Ojolo et al., 2022).

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Nigeria confronts a critical and unsustainable paradox: despite possessing immense potential for renewable energy and sustainable agriculture through biogas-based farming systems (BBFS), the widespread adoption and successful implementation of this technology remain remarkably low and fraught with failure. The nation's agricultural sector is plagued by soil degradation, high input costs, and low productivity, while its population suffers from acute energy poverty and environmental harm from heavy reliance on traditional biomass like firewood and charcoal (IEA, 2022). Biogas technology, which converts abundant organic waste into clean energy and organic fertilizer, presents a proven, integrated solution to these interlinked challenges, with studies indicating the livestock sector alone could generate over 25 billion cubic meters of biogas annually (Ojolo et al., 2022).

However, the transition from technical potential to practical, widespread application has been largely unsuccessful. Decades of intermittent promotion by government and international donors have resulted in a landscape littered with failed, abandoned, or underperforming biogas installations (Olanrewaju et al., 2023). This persistent cycle of project failure represents a significant waste of financial and social capital and a profound lost opportunity for sustainable development. The core problem, therefore, is that a complex, multifaceted set of constraints continues to systematically inhibit the effective adoption, proper functioning, and long-term sustainability of biogas-based farming systems across Nigeria's diverse socio-economic and agro-ecological contexts.

Current understanding of these barriers is fragmented and often anecdotal. While existing literature identifies broad categories of constraints such as high upfront capital costs and financing gaps (Dahunsi & Olayanju, 2022), technical issues related to design and maintenance (Akinbami et al., 2021), and socio-cultural resistance (Ajayi & Omonijo, 2023) there is a lack of a comprehensive, contemporary, and empirical analysis. Specifically, a gap exists in research that systematically diagnoses, prioritizes, and elucidates the interactions among these factors within the current Nigerian policy and economic landscape (Oladokun & Ogunjuyigbe, 2024). Without this precise and holistic diagnostic, interventions by stakeholders remain uncoordinated and misdirected, often addressing symptoms rather than root causes, which leads to repeated cycles of investment and failure (Eze et al., 2024). The main objective of the study is to examine the constraints affecting the adoption and implementation of biogas-based farming systems in Taraba State, Nigeria. The specific objectives of the study are to:

- Describe the socioeconomic characteristic of the respondents in biogas-based farming systems Taraba State.
- Identify the constraints affecting the adoption and implementation of biogas-based farming systems in Taraba State.

2. Methodology

2.1. Description of the Study Area

This study is conducted in Taraba State, a region of significant agricultural and ecological importance in North-Eastern Nigeria. Geographically, the state is positioned approximately between Latitudes 6° 30' and 9° 36' North and Longitudes 9° 40' and 11° 50' East, encompassing a land area of about 54,473 square kilometers within the expansive Benue River basin (Taraba State Government, 2023). It shares its boundaries with Bauchi and Gombe States to the north, Plateau and Nasarawa States to the west, Benue and Cross River States to the south, and the Republic of Cameroon to the east, placing it within a vital transnational and inter-state ecological corridor (National Bureau of Statistics, 2022).

Demographically, Taraba State is projected to have a population exceeding 3.5 million inhabitants, based on growth rate extrapolations from the last official census (National Population Commission, 2006; World Bank, 2023). This population is remarkably diverse, comprising numerous ethnic groups and tribes. The major tribes include the Fulani, Jukun, Chamba, Tiv, Kuteb, Ichen, Mumuye, and Mambilla, with the Fulani and Jukun being among the most populous, contributing to a rich cultural tapestry and varied traditional agricultural practices (Adebayo, 2021).

Climatologically, the state experiences a tropical climate characterized by distinct wet and dry seasons. It transitions from the Sudan Savannah in the north to the Guinea Savannah in the central regions, with the Mambilla Plateau in the south exhibiting a unique temperate highland climate (Oluwasanya, 2020). The rainfall pattern is highly seasonal, with precipitation typically occurring from April to October. Annual rainfall totals range from about 1,200 mm in the northern savannah areas to over 2,000 mm on the elevated Mambilla Plateau, which directly dictates the cropping calendar and agricultural productivity (Akinsanola & Ogunjobi, 2017). Consequently, temperature conditions vary with topography, averaging 28°C to 35°C in the lowlands but dropping to a cooler 18°C to 25°C on the Plateau (FMEnv, 2020).

The state's soil types are closely linked to its climate and vegetation zones. The predominant soils are ferruginous tropical soils (ultisols), which are common in the savannah regions and are moderately fertile but prone to nutrient depletion (FDALR, 2022). The floodplains of major rivers like the Benue and Taraba are endowed with rich alluvial soils, while the Mambilla Plateau features fertile volcanic and loamy soils that are highly conducive to both staple and cash crop cultivation (Ibrahim et al., 2019).

Economically, Taraba State is predominantly agrarian, with the sector serving as the backbone of livelihoods and economic output. Agricultural activities are diverse, encompassing the cultivation of staple food crops such as maize, sorghum, rice, yams, and cassava across the state (Taraba Agricultural Development Program, 2021). Critically, the state is a national leader in the production of several cash crops, notably tea and Arabica coffee on the Mambilla Plateau, as well as sesame (beniseed), groundnuts, and cotton in other zones (CBN, 2022). Livestock rearing, especially cattle pastoralism, is a major complementary economic activity, particularly among the Fulani ethnic group (Babatunde, 2020). Other significant economic activities include commerce, fishing along its river systems, and small-scale mining. This confluence of a large agrarian population, diverse crop and livestock systems, and significant organic waste generation presents a highly relevant context for investigating the potential of an integrated biogas system to enhance sustainability, energy access, and soil fertility.

2.2. Source and Methods of Data Collection

For the purpose of this study, primary data was used. This was obtained by the use of structured questionnaire which was administered to farmers in the study area. The other sources of information consist of records from Taraba State Agriculture Development Programme (TADP)

2.3. Sampling procedure

Multi-stage and purposive sampling techniques was used in selecting the farmers for the study. First stage sampling involved a purposive selection of two (2) Local Government Area in each of the senatorial zones to give a total of six (6) Local Government Area, the second stage involved selection of two (2) wards in each of the selected Local Government Area to give a total of 12 wards for the study, third (3) stage involved random selection of two (2) villages from each of the selected wards to give a total of 24 villages for the study. In stage four (4), a simple random sampling technique of 359 was obtained from the population size of 3,503 using the Yamane's formula as given below. However only 346 questionnaires were return with useful information.

$$N = \frac{N}{1+N\,(e)2}$$

Where

- N = Sample sizes
- N = Number of farmers (sampling frame)
- e = Margin error (usually 5%)

2.4. Methods of Data Analysis

Descriptive statistics (means, frequencies and percentages) and tables were employed to describe the socio-economic characteristics of the farmers. A 5-point Likert scale was used to identify the constraints affecting the adoption and implementation of biogas-based farming systems. The mean scores of the responses were categorized as follows: > 4.5 = Strongly Agree (SA); 3.5 – 4.4 = Agree (A); 2.5 – 3.4 = Undecided (U); 1.5 – 2.4 = Disagree; < 1.5 = Strongly Disagree

3. Results and discussion

3.1. Socio-economic Characteristics of Respondents

The distribution of the respondents according to their socio-economic characteristics is presented in the Table 1. The results show that 275 respondents (79.48%) were male, while 71 respondents (20.52%) were female. The dominance of male respondents indicates that farming and technology-related decision-making in the study area is largely controlled by men. This pattern is common in rural Nigeria where men have greater access to land, livestock, and capital required for technologies such as biogas systems. Bello and Musa (2021) observed that male farmers are more likely to participate in sustainable agricultural innovations due to their stronger control over productive resources. This finding suggests the need for gender-inclusive policies to enhance women's participation in integrated biogas farming.

Most respondents were between 41–50 years (49.42%), followed by those aged 31–40 years (35.26%). The mean age was 41 years. The predominance of middle-aged farmers indicates that respondents are within the economically active and productive age group. Farmers in this age category often combine physical strength with farming experience, making them more capable of adopting and sustaining integrated biogas systems. According to Abdulrahman et al. (2022), middle-aged farmers are more receptive to renewable energy technologies because they are better positioned to evaluate long-term benefits and risks. This age distribution is therefore favorable for sustainable biogas farming in Taraba State.

The majority of respondents were married (89.60%), while only 10.40% were single. The high proportion of married respondents suggests increased household responsibilities, particularly energy consumption and waste management, which can motivate interest in biogas technology. Oladimeji and Yusuf (2020) noted that married farmers are more inclined to adopt sustainable farming practices due to higher household needs and availability of family labor. Thus, marital status may positively influence the adoption of integrated biogas systems

About 53.89% of respondents had household sizes of 6–10 persons, with a mean household size of 7. Large household sizes imply availability of family labor and increased generation of organic waste, both of which are important for biogas production. Adebayo et al. (2023) reported that households with larger family sizes benefit more from biogas systems because of higher cooking energy demand and sufficient feedstock supply. Therefore, household size enhances the suitability of integrated biogas farming systems in the study area.

Most respondents (36.99%) had 11–15 years of farming experience, with a mean farming experience of 17 years. The relatively long years of farming experience indicate that respondents possess adequate practical knowledge to manage integrated farming technologies. Garba and Mohammed (2021) found that farming experience significantly influences farmers' confidence and willingness to adopt sustainable agricultural innovations. This suggests that the experienced farmers in Taraba State are well-positioned to manage integrated biogas systems effectively.

More than half of the respondents (56.36%) attained secondary or tertiary education, while only 11.56% had no formal education. Education enhances farmers' ability to understand, operate, and maintain biogas systems. Umar et al. (2024) emphasized that educated farmers are more likely to adopt renewable energy technologies because they can easily comprehend technical information and training. The relatively high level of education among respondents therefore supports the potential adoption and sustainability of integrated biogas systems in Taraba State.

Personal savings were the major source of finance (59.25%), followed by borrowed funds (21.97%) and assistance from friends and relatives (18.79%). The heavy reliance on personal savings indicates limited access to formal financial institutions for agricultural investment. Lawal and Adekunle (2022) observed that dependence on personal savings constrains farmers' ability to invest in capital-intensive technologies such as biogas digesters. This finding highlights the need for improved financial support mechanisms to promote integrated biogas farming.

Only 26.30% of respondents had access to credit, while 73.70% had no access. Limited access to credit poses a significant challenge to the adoption of integrated biogas systems due to their initial capital requirements. Sadiq et al. (2020) reported that access to credit plays a critical role in enhancing farmers' adoption of sustainable agricultural technologies. Improving credit availability would therefore enhance participation in integrated biogas farming in the study area. Most respondents (54.62%) cultivated farm sizes of 1–2 hectares, with a mean farm size of 2.7 hectares. The dominance of small-scale farms suggests that biogas technologies must be adapted to suit smallholder farmers. Ibrahim and Danjuma (2025) noted that while larger farm sizes increase adoption probability, smallholders can also adopt sustainable technologies when they are appropriately scaled or implemented through cooperative arrangements. This implies that small-scale and community-based biogas systems are most suitable for Taraba State.

Table 1 Socio-economic characteristics of the Respondents (n=346)

Sex	**Frequency**	**Percentage**
Male	275	79.48
Female	71	20.52
Age		
21-30	8	2.31
31-40	122	35.26
41-50	171	49.42
≥ 50	45	13.01
Mean	41	
Marital Status		
Single	36	10.40
Married	310	89.60
Household Size		
1-5	83	23.99
6-10	183	53.89
11-15	58	16.76
≥16	22	6.36
Mean	7	
Farming Experience (Years)		
1-5	38	10.98
6-10	101	29.19
11-15	128	36.99
16-20	42	12.14
≥ 21	37	10.69
Mean	17	
Level of Education		
No formal	40	11.56
Primary	111	32.08
Secondary	144	41.62
Tertiary	51	14.74
Sources of Finance		
Personal Savings	205	59.25
Borrowed	76	21.97
Friends and Relative	65	18.79
Access to Credit		
Access	91	26.30

No Access	255	73.70
Farm Size (ha)		
<1 – 2	189	54.62
3 – 4	105	30.35
>4	52	15.03
Mean	2.7	

Source: Field Survey, 2025

3.2. Constraints Affecting the Adoption and Implementation of Biogas-Based Farming Systems

The analysis of constraints affecting the adoption and implementation of biogas-based farming systems is presented in Table 2. The majority of respondents strongly agreed that many farmers lack access to credit or loans to install biogas (66.76%) and agreed (21.10%) that limited access to credit is a constraint. The mean score was 4.46, indicating strong agreement. Limited access to credit is a significant barrier to adopting capital-intensive technologies like biogas. Bello and Ibrahim (2021) reported that access to financial resources is crucial for smallholder farmers to invest in renewable energy technologies. Without loans or credit facilities, many farmers are unable to install biogas systems, despite understanding their potential benefits.

About 21.68% strongly agreed that the cost of installing a biogas system is too high and 54.34% agreed. The mean score was 3.80, indicating agreement. High installation costs deter farmers from adopting biogas systems. Abdullahi and Umar (2022) noted that the upfront cost of biogas technology is a major impediment, particularly for small-scale farmers with limited capital. This highlights the need for cost-reducing strategies or subsidized programs to enhance adoption.

Nineteen percent strongly agreed that there is insufficient government or NGO support for biogas and 56.07% agreed, giving a mean score of 3.79, indicating agreement. Support from government and NGOs, in the form of training, subsidies, or awareness campaigns, is crucial for technology adoption. Lawal and Sadiq (2021) emphasized that inadequate institutional support limits the spread of renewable energy technologies in rural areas. Enhancing institutional involvement could accelerate biogas adoption in Taraba State.

Eighteen percent strongly agreed that there is inadequate technical knowledge about biogas in the community and 53.76% agreed, with a mean score of 3.68, indicating agreement. Limited technical know-how prevents farmers from effectively installing, operating, and maintaining biogas systems. Umar and Musa (2023) highlighted that insufficient technical skills reduce confidence in using renewable energy technologies and may lead to misuse or abandonment. Training programs and technical support are therefore essential to overcome this constraint.

Only 8.38% strongly agreed that spare parts and maintenance services are not easily available. and 21.10% agreed, while 43.93% disagreed. The mean score of 2.69 indicates undecided.Although some farmers perceive a lack of maintenance services as a constraint, the undecided response suggests mixed experiences. Sadiq and Abdullahi (2022) observed that accessibility to spare parts and skilled maintenance is critical for sustaining biogas adoption. Establishing local supply chains and service centers could mitigate this challenge.

Only 11.56% strongly agreed that cultural or religious beliefs discourage the use of biogas. and 16.76% agreed, while 34.97% disagreed. The mean score of 2.56 indicates undecided. Cultural and religious perceptions have a minor influence on biogas adoption in Taraba State. Abdullahi and Yusuf (2022) noted that although traditional beliefs may occasionally affect acceptance of renewable technologies, technical and economic factors are usually more decisive. Awareness campaigns can further minimize potential cultural barriers.

Only 9.83% strongly agreed that lack of awareness is a major barrier to biogas adoption and 17.63% agreed, while 42.20% disagreed. The mean score of 2.56 indicates undecided. While some farmers perceive low awareness as a constraint, most respondents disagreed, suggesting that knowledge of biogas exists but may not translate into adoption. Ogunleye et al. (2021) emphasized that awareness alone is insufficient for adoption; financial capacity, technical skills, and institutional support are equally critical. This finding aligns with earlier results highlighting credit and cost as more significant barriers.

Table 2 Constraints Affecting the Adoption and Implementation of Biogas-Based Farming Systems. (n=346)

S/N	Statement	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree	Total	Mean	Remark
1	Many farmers lack access to credit or loans to install biogas	231 (66.76)	73 (21.10)	20 (5.78)	15 (4.34)	7 (2.02)	1544	4.46	Strongly Agree
2	The cost of installing a biogas system is too high	75 (21.68)	188 (54.34)	41 (11.85)	22 (6.36)	20 (5.78)	1314	3.80	Agree
3	There is insufficient government or NGO support for biogas	67 (19.36)	194 (56.07)	45 (13.01)	25 (7.23)	15 (4.34)	1311	3.79	Agree
4	There is inadequate technical knowledge about biogas in the community	65 (18.79)	186 (53.76)	43 (12.43)	23 (6.65)	29 (8.38)	1273	3.68	Agree
5	Spare parts and maintenance services are not easily available	29 (8.38)	73 (21.10)	49 (14.16)	152 (43.93)	43 (12.43)	931	2.69	Undecided
6	Cultural or religious beliefs discourage the use of biogas	40 (11.56)	58 (16.76)	43 (12.43)	121 (34.97)	84 (24.28)	887	2.56	Undecided
7	Lack of awareness is a major barrier to biogas adoption	34 (9.83)	61 (17.63)	37 (10.69)	146 (42.20)	68 (19.65)	885	2.56	Undecided

Source: Field Survey, 2025; Note: > 4.5 = Strongly Agree (SA); 3.5 – 4.4 = Agree (A); 2.5 – 3.4 = Undecided (U); 1.5 – 2.4 = Disagree; < 1.5 = Strongly Disagree

4. Conclusion and recommendations

The study confirms that biogas-based farming systems (BBFS) represent a viable, integrated solution to the interconnected challenges of energy poverty, agricultural stagnation, and environmental degradation in Taraba State, Nigeria. The socio-economic profile of farmers predominantly middle-aged, experienced males with moderate education and large households indicates a demographic with the capacity to adopt and manage such systems, given adequate support. However, the transition from potential to widespread adoption is critically constrained by a few dominant barriers.

The findings reveal that adoption is primarily hampered by severe financial and institutional constraints. The prohibitive upfront cost of installation and a pronounced lack of access to credit emerged as the most significant barriers, strongly limiting farmers' ability to invest. This is compounded by insufficient technical knowledge and a perceived absence of sustained government or NGO support for training, subsidies, and extension services. In contrast, factors such as cultural beliefs, lack of awareness, and availability of maintenance services were not considered major impediments by the majority of respondents, suggesting that the core challenges are economic and technical rather than socio-cultural.

Therefore, without targeted interventions to address these specific financial, technical, and institutional bottlenecks, the promise of biogas technology to enhance sustainable farming and energy access in Taraba State will remain largely unrealized, perpetuating the cycle of project failure and lost developmental opportunity. Based on the findings of this study, the following recommendations are proposed to facilitate the adoption and implementation of biogas-based farming systems in Taraba State:

- **Develop and Promote Targeted Financial Mechanisms**: Government agencies, in partnership with microfinance institutions and development banks, should design and implement accessible credit schemes, soft loans, or matched-grant programs specifically for smallholder farmers to offset the high initial capital cost of biogas digesters. This could be integrated into existing agricultural intervention funds.
- **Strengthen Institutional Support and Capacity Building**: The Taraba State Ministry of Agriculture, in collaboration with NGOs and technical training institutes, should establish a dedicated biogas extension program. This program should provide continuous hands-on training for farmers on digester construction, operation, maintenance, and the effective use of digestate as fertilizer, thereby bridging the technical knowledge gap.
- **Facilitate the Development of a Local Supply and Service Ecosystem**: The government should incentivize local entrepreneurs and fabricators through start-up grants or tax relief to establish small businesses that supply affordable, locally adapted biogas components and offer routine maintenance and repair services. This will address long-term sustainability concerns and create green jobs.
- **Implement a Pilot Demonstration and Awareness Programme**: Stakeholders should prioritize the establishment of well-managed, functional demonstration units in each senatorial zone. These units should serve as practical learning centers to showcase the economic and agronomic benefits of BBFS, moving beyond abstract awareness to proven evidence, thereby stimulating demand and guiding effective policy formulation.

Compliance with ethical standards

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

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