https://iphopen.org/index.php/a
Online ISSN: 3050-8843 Print ISSN: 3050-9297

DETERMINANTS OF ALLOCATIVE EFFICIENCY IN BAMBARA GROUNDNUT PRODUCTION IN NORTHEAST NIGERIA: A GENDER-BASED ANALYSIS

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ABSTRACT

In gendered agricultural systems, disparities in resource access, decision-making authority, and socio-economic constraints may lead to significant differences in allocative efficiency between male and female farmers. This study investigates gender differences in allocative efficiency among Bambara groundnut farmers in Northeast Nigeria.The objectives include estimating the economic efficiency of Bambara groundnut farmers, comparing the economic efficiency of Bambara groundnut farmers, and analyzing the determinants of economic efficiency of Bambara groundnut in Northeast, Nigeria. The study adopted a survey design. A multistage sampling technique was used to select a total of 360 male and 360 female smallholder Bambara groundnut farmers from three selected states including Adamawa, Bauchi, and Taraba States. Primary data was collected from the respondents using a well-structured questionnaire. Data were analysed using descriptive statistics and econometric techniques, including the, Cobb-Douglas stochastic frontier cost function model, independent z-test, and censored Tobit regression model. Findings reveal that female farmers demonstrated superior allocative efficiency compared to their male counterparts across all states and the wider Northeast Region. Determinants of allocative inefficiency varied by gender. For male farmers, key factors included age, education, farming experience, extension visits, cooperative membership, credit obtained, land ownership, and training in Bambara farming. For female farmers, significant determinants were age, household size, farming experience, extension visits, cooperative membership, distance to farm, security challenges, and off-farm income. These findings suggest the need for gender-responsive policies aimed at improving allocative efficiency, particularly through enhanced access to credit, extension services, cooperative networks, and security interventions.

Keywords: *Gender, Allocative efficiency, Bambara groundnut farming, Northeast Nigeria*

DOI:-10.5281/zenodo.16881279 **Manu script ID # 312**

1. INTRODUCTION

In recent years, agricultural systems across sub-Saharan Africa have encountered growing demands to address various developmental objectives, including boosting productivity, ensuring food and nutrition security, and enhancing rural livelihoods. The agricultural sector in Nigeria contributes approximately 24% to the gross domestic product and supports around 70% of the rural population (World Bank, 2023). However, significant inefficiencies persist within the system, particularly in the allocation of production resources among smallholder farmers. Addressing these inefficiencies is crucial for achieving broader economic and developmental goals. One approach to this is through the assessment and improvement of allocative efficiency, particularly in the context of underutilized but high-potential crops such as Bambara groundnut (*Vigna subterranea*).

Bambara groundnut (BG), a drought-resilient legume native to sub-Saharan Africa, has gained recognition for its adaptability to marginal environments, nutritional value, and ability to enhance soil fertility through nitrogen fixation. The crop's ability to thrive in less fertile soils and its superior yields compared to other legumes such as groundnuts and beans under drought conditions makes it a vital crop for ensuring food security in arid and semi-arid regions (Nafula et al., 2021). Its seeds contain up to 19% protein, 63% carbohydrate, and essential micronutrients, making it a valuable food security crop (Ajilogba et al., 2022; Adegboyega et al., 2021). Predominantly cultivated in West Africa, specifically in countries such as Nigeria, Burkina Faso, Niger, and Cameroon, which collectively contribute to 74% of global production, Bambara groundnut is also cultivated, albeit in smaller quantities, in regions such as Southeast Asia, the United States, and Australia (Majola et al., 2021). Within the West African region, Nigeria stands out as a primary producer, contributing a substantial 33,000 to 49,000 tonnes to the annual global production of approximately 330,000 tonnes (Godwin & Moses, 2014). Bambara groundnut cultivation is frequently linked to small-scale, subsistence farming practices, with women playing a significant role in both production and processing (Tan et al., 2020; Temegne et al., 2020). Bambara groundnut is the third most consumed and cultivated food legume in Africa, following groundnut and cowpea (Ibny et al., 2019). Despite these attributes, BG remains largely underutilized in Nigeria's agricultural planning, research investments, and policy frameworks.

Cultivation is often small-scale, characterized by traditional methods, limited market access, and inadequate extension services. In northeast Nigeria, a region plagued by climatic extremes, insecurity, and poverty, Bambara nut production remains underexploited despite its ecological and economic suitability. A distinct aspect of Bambara nut farming is its gendered nature. Women are heavily involved in its cultivation, often managing production from planting to processing. Nevertheless, gender disparities in access to productive resources such as land, credit, and extension services limit women's agricultural efficiency (FAO, 2021). These inequalities are particularly pronounced in northeast Nigeria, where socio-cultural norms and institutional limitations restrict women's full participation in agribusiness opportunities. Consequently, analyzing allocative efficiency through a gender lens is essential for evidence-based and inclusive agricultural policy. Allocative efficiency in agricultural economics refers to a farmer's ability to allocate inputs in proportions that reflect both their relative prices and marginal productivity, with the goal of maximizing output or minimizing cost. It is a key component of overall economic efficiency, complementing technical efficiency. In environments where input markets are imperfect and access to resources is unequal, as is the case in much of rural Nigeria, allocative inefficiency can significantly hinder productivity and farm profitability (Dagachi & Olorunsanya, 2023; Yohannis, 2020). Recognizing how gender dynamics shape input use decisions and farm-level outcomes is, therefore, indispensable for promoting equitable and sustainable agricultural development.

Several studies have highlighted the low productivity and inefficient use of inputs among smallholder farmers in Nigeria, but relatively few focus on the role of gender in determining allocative efficiency. The limited body of literature that does address this tends to generalize findings, ignoring the nuanced socio-economic and cultural factors that influence decision-making for male and female farmers (Henry et al., 2023). This oversight constrains the formulation of targeted interventions that can address the unique constraints faced by women in agriculture. Additionally, northeast Nigeria has witnessed increased vulnerability in recent years due to insecurity from insurgency and banditry, which have disrupted farming activities, displaced households, and fractured rural markets. These challenges exacerbate already existing inefficiencies and disproportionately affect women, who are more likely to experience mobility restrictions and loss of productive assets in times of crisis. Thus, a focused analysis of allocative efficiency in this region is not only timely but also policy-relevant as this will account for gender-specific vulnerabilities.

Despite the agronomic and socio-economic potential of Bambara groundnut, its production in northeast Nigeria is still constrained by suboptimal resource use and a lack of supportive infrastructure. Farm-level inefficiencies, particularly in the allocation of critical inputs like labor, land, seeds, and agrochemicals, persist due to inadequate extension services, poor access to formal credit, and market imperfections. These constraints are

further intensified by gender-based disparities in resource access, land ownership rights, and institutional representation. Women, although significantly involved in BG production, often operate on smaller plots, have less access to modern inputs, and are underrepresented in cooperatives and extension networks. Current empirical literature in Nigeria has inadequately addressed these issues from a gender-disaggregated allocative efficiency perspective.

Most available studies focus on technical or economic efficiency without isolating the allocative dimension, or they aggregate data across genders, thereby masking underlying disparities. This lack of nuanced evidence undermines the capacity of policy makers to design effective, equitable interventions aimed at improving productivity and rural welfare. Furthermore, climate variability, insecurity, and population pressure in northeast Nigeria have led to shrinking farm sizes and increased competition for agricultural resources, further complicating efficiency and sustainability. These conditions necessitate a more efficient use of available resources among smallholder farmers who depend on agriculture for their livelihood. Without a clear understanding of the determinants of allocative efficiency and how they vary by gender, interventions may continue to be generic and ineffective. Against this backdrop, this study aimed to investigate the determinants of allocative efficiency in Bambara groundnut farming in Northeast Nigeria through a gender-based analytical lens.

Specifically, the study seeks to:
1. Estimate the allocative efficiency levels of male and female Bambara groundnut farmers in the study area;
2. Compare the allocative efficiency levels of male and female Bambara groundnut farmers; and
3. determine the factors that significantly influence allocative efficiency among male and female Bambara groundnut farmers in the study area.

This study addresses a critical gap in the literature by focusing on the gender-specific drivers of allocative efficiency in the context of an underutilized yet highly relevant crop. By producing disaggregated empirical evidence, it enables more precise targeting of agricultural interventions. It also informs policy dialogues around gender equity in agriculture. Understanding where and why efficiency gaps exist between male and female farmers will enable governments, development agencies, and NGOs to design inclusive policies that bridge these gaps which include enhancing productivity and rural welfare.

Materials and Methods

The Study was conducted in Northeast, Nigeria. The area is one of the zones in Nigeria. The states in this area includes: Adamawa, Bauchi, Borno, Gombe, Taraba, and Yobe. It shares boundaries with Chad Republics and Cameroon to the east, Plateau and Benue States to the South, Kano and Jigawa States to the West and Niger Republic to the North. The area lies between latitudes 7^{o} 30' and 14^{o} North of the equator and longitudes 9^{o} and 15^{o} East of the Greenwich meridian. It occupies less than one-third of Nigeria's total area and have population of 26 million, or 12% of the country's population (Worldometer, 2021). Major crops grown in the area include cassava, rice, yam, maize, millet, potato, sorghum, cowpea, cotton, groundnut, Bambara nut, and water melon (Ojanuga, 2006). The farmers are also known for rearing of livestock. In selecting respondents for this study, a multi-stage sampling was used for this study.

Out of the six States in the North East; Adamawa, Bauchi, Borno, Gombe, Taraba and Yobe, a purposive sampling method was used first to select three States out of the six states in the zone, this is based on the availability of valid household Bambara nut farmers in the study area. The states with the evidence of valid or contact household Bambara nut farmers were selected for the study. The States are Adamawa State, Bauchi State and Taraba State. The second stage is a purposive selection of six local government areas from each of the selected state that showed evidence of household Bambara nut farmers in the area making it a total of eighteen (18) local government areas. Thirdly two communities were randomly selected from each local government area making it a total of thirty six (36) communities. From each community, a stratified random sampling technique was used to select ten (10) female and ten (10) male Bambara nut farmers making three hundred and sixty (360) male and three hundred and sixty (360) female Bambara nut farmers. In total, seven hundred and twenty (720) Bambara nut farmers were used for this study.

The sample frame which is the list of Bambara Nut farmers in the selected communities were compiled with the assistance of staff of Agricultural Development Programme (ADP), resident extension agents, officials of farmers association and community leaders. Primary data, collected with the aid of a well-structured questionnaire were used in the study.

The Cobb-Douglas Stochastic frontier production function that was used to determine the allocative efficiency of male as well as female Bambara groundnut farmers in Northeast Nigeria is expressed in its implicit form as used by Farrell (1975) and Degefa, Jaleta, and Legesse (2017) as:

$$AE_i = \frac{EE_i}{TE_i} -(1)$$

The differences in the allocative efficiency (AE) estimate in equation (1) between the male and female BG farmers in northeast Nigeria were tested using the independent z-test. The z-test is fitted as:

$$z_{cal} = \frac{(\bar{x}_1 - \bar{x}_2)}{S_{\bar{x}_1 - \bar{x}_2}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (2)$$

$$S_{\bar{x}_1 - \bar{x}_2} = \sqrt{\frac{s_{x_1}^2}{n_1} + \frac{s_{x_2}^2}{n_2}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (3)$$

Where;

$\bar{x}_1$ = Mean of technical efficiency or economic efficiency or allocative efficiency of male Bambara groundnut producers.

$\bar{x}_2$ = Mean of technical efficiency or economic efficiency or allocative efficiency of female Bambara groundnut producers.

$s_{x_1}^2$ = Standard deviation of technical efficiency or economic efficiency or allocative efficiency of male Bambara groundnut producers.

$s_{x_2}^2$ = Standard deviation of technical efficiency or economic efficiency or allocative efficiency of female Bambara groundnut producers.

n_1 = numbers of male respondents.

n_2 = numbers of female respondents.

For objective three of the study, the AE estimate from equation (1) was regressed using a censored Tobit model on farmer specific explanatory variables that explained variation inefficiency across farmers. This was done to identify the inefficiency factors that influenced the allocative efficiency of both male and female farmers in the area of study. The distribution of the estimated efficiencies in equation (1) is censored at the value 1. The Tobit model (Tobin, 1958) is specified as:

$$E_i^* = \sum_{j=0}^{n} \beta_j D_j + V - - - - - - - - - - - - - - - (4)$$

$E_i = E_i^*$ if $E_i^* > 0$ and $E_i = 0$ if $E_i^* \leq 0$

Where, E_i is an efficiency score representing AE; V~N (0, δ_2); β_j are vector parameters to be estimated; V is the error term, assumed to be normally distributed and E_i^* is latent variable with E $[E_i^*/D_i]$ equals $D_i\beta$; and D_j represents various Bambara nut farmer-specific variables.

Where;

D_1= Age of farmer (years)
D_2= Level of education (years of formal schooling)
D_3= Household size (number of people per farmer's household)
D_4 = Farming experience of the farmer (number of years in Bambara nut production)
D_5 = Extension visits (number of visits per production cycle)
D_6 = Cooperative membership (1 = Member; 0 = Non-member)
D_7 = Amount of credit obtained (₦)
D_8 = Distance to farm (Km)
D_9 = Banditry/herdsmen attacks of farmers on farms or in the community (Dummy, Yes = 1; No = 0)
D_{10} = Perceived price hike of product (Dummy, Yes = 1; No = 0)
D_{11} = Land ownership status (Inheritance = 1; Otherwise = 0)
D_{12} = Training in Bambara groundnut farming (Yes = 1; No = 0)
D_{13} = Off farm income (₦)

The full log-likelihood of the Tobit model is comprised of two components. The initial component corresponds to the conventional regression for the unaltered observations, while the subsequent component corresponds to the pertinent probabilities that a given observation is censored (Tobin, 1958). This model is an econometric model that is utilized when the dependent variable is constrained or censored in both directions (Tobin, 1958). If the Ordinary Least Square (OLS) method is directly employed, it would result in subjective and unreliable estimation of coefficients. Consequently, the Tobit model, which adheres to the principle of maximum likelihood, presents an improved alternative for estimating regression coefficients (Greene, 2000).

RESULTS AND DISCUSSION

Estimation of the Allocative Efficiency of Male and Female Bambara Groundnut Farmers

The Cobb-Douglas Stochastic Frontier production function was employed to assess the allocative efficiency of both male and female Bambara groundnut farmers in Northeast Nigeria. The allocative efficiency score was estimated as the quotient of economic efficiency and technical efficiency following Farrell (1975) and Degefa, Jaleta, and Legesse (2017). Table 1 presents the result of the level of allocative efficiency of the male and female farmers in the study area.

The result in Table 1 shows that male BG farmers' AE scores ranged from 0.448 to 0.992, with the majority (41.9%) achieving scores between 0.701 and 0.800. The smallest group (1.1%) had scores between 0.401 and 0.500, resulting in a mean AE score of 0.764. Female BG farmers exhibited scores ranging from 0.555 to 0.950, with the majority (54.2%) scoring between 0.801 and 0.900, and the smallest group (0.3%) scoring between 0.501 and 0.600. The mean AE score for female farmers was 0.837. This overall data indicates that female BG farmers are more allocatively efficient than their male counterparts across the region, further highlighting their superior efficiency and commitment to Bambara nut farming.

Table 1: Level of allocative efficiency of male and female BG farmers in northeast Nigeria

Allocative Efficiency Level	Male		Female	
	Frequency	Percent	Frequency	Percent
0.401 - 0.500	4	1.1	-	-
0.501 - 0.600	14	3.9	1	0.3
0.601 - 0.700	64	17.8	17	4.7
0.701 - 0.800	151	41.9	70	19.4
0.801 – 0.900	100	27.8	195	54.2
0.901 – 1.000	27	7.5	77	21.4
Total	360	100	360	100
Mean	0.764		0.837	
Maximum	0.992		0.950	
Minimum	0.448		0.555	

Source: Field survey data, 2024

The mean score of AE result indicates that on average a male farmer could increase Bambara nut output by 23.6%, if he used the right inputs and produced the right output relative to input costs and output price. The most allocative inefficient male BG farmer would have an efficiency gain of 54.84% derived from (1-0.448/0.992)*100) to attain the level of the most technically efficient producer. Similarly, the mean score of AE result indicates that on average a female farmer could increase Bambara nut output by 16.30%, if she used the right inputs and produced the right output relative to input costs and output price. The most allocative inefficient female BG farmer would have an efficiency gain of 41.58% derived from (1- 0.555/0.950)*100) to attain the level of the most technically efficient producer. The findings from the analysis indicate that female Bambara groundnut (BG) farmers exhibit higher allocative efficiency (AE) than their male counterparts, with a mean AE score of 0.837 compared to 0.764 for male farmers. This disparity underscores the superior ability of female farmers to optimise their inputs and outputs to maximise profits.

Recent empirical studies corroborate these findings. For instance, Umar et al. (2022) identified that female crop farmers generally demonstrate higher allocative efficiency compared to male farmers, attributing this to their more active involvement in farm management and decision-making processes. Moreover, Mohammed et al. (2020) found that female farmers in the region are more inclined to adopt new technologies and innovations, which enhances their allocative efficiency. The data also reveals significant potential for improvement in allocative efficiency among both male and female farmers. Specifically, the most allocatively inefficient male farmers could achieve efficiency gains of up to 54.84%, while the most allocatively inefficient female farmers could realise gains of up to 41.58%. This indicates that, despite the observed gender differences in AE, there is considerable room for both groups to enhance their efficiency.

These findings emphasise the critical importance of targeting female farmers in agricultural development programs. Providing targeted training and support to improve allocative efficiency among all farmers, particularly female farmers, can lead to substantial improvements in agricultural productivity and profitability. Adewuyi et al. (2021) and Ibeawuchi et al. (2023) highlight the effectiveness of such interventions in enhancing farm efficiency and promoting sustainable agricultural development.

Comparison of the Allocative Efficiency of Male and Female Bambara groundnut Farmers

The result of the independent z-test used to test the significance difference in allocative efficiency between male and female Bambara groundnut farmers in Northeast Nigeria is presented in Table 2. The results in Table 2 indicate that female farmers exhibited significantly higher AE than male farmers ($z = -11.475$, $p < 0.01$). The finding reveals a higher allocative efficiency among female Bambara groundnut farmers compared to their male counterparts in Northeast region.

Table 2: Test of significance difference in allocative efficiency between male and female Bambara groundnut farmers in Northeast Nigeria

Variable	Mean	Std. Deviation	Std. Error Mean	Df	z-statistic
Male	0.767	0.100	0.005		
Female	0.837	0.071	0.004		
Difference	-0.071	0.117	0.006	718	-11.475***

Source: Field survey data, 2024

Note: *** signifies 1% level of significance.

This suggests that female farmers are more effective in optimising their resources and decision-making, leading to superior allocative efficiency. Recent empirical studies support these findings, with Adebayo et al. (2021) and Onu and Abba (2020) reporting that female farmers achieve higher allocative efficiency due to their effective management of resources and decision-making capabilities. Additionally, Oladimeji and Abdulsalam (2019) found that female farmers' increased access to training and extension services has positively impacted their allocative efficiency. These studies collectively emphasise the importance of addressing gender disparities in resource allocation to maximise agricultural productivity and economic efficiency in Nigeria.

Determinants of Allocative Inefficiency of Male and Female BG Farmers

The determinants of allocative inefficiency of male and female Bambara groundnut farmers in northeast Nigeria was done using the censored Tobit regression model. The result of the determinants of allocative inefficiency of male and female Bambara groundnut farmers in northeast Nigeria is presented in Table 3

Table 3: Tobit estimates of the determinants of allocative inefficiency of male and female Bambara groundnut farmers in northeast Nigeria

Variable	Parameters	Male Coefficient	z-values	Female Coefficient	z-values
Constant	β_0	0.868	6.198***	0.833	7.818***
Age of farmer	β_1	-0.121	-3.199***	-0.135	-2.358**
Level of education	β_2	-0.021	-2.121**	0.009	1.226
Household size	β_3	0.016	1.595	0.001	2.195**
Farming experience	β_4	0.027	2.383***	0.153	3.352***
Extension visits	β_5	-0.265	-3.932***	0.015	2.437**
Cooperative membership	β_6	0.092	2.117**	0.086	2.142**
Amount of credit obtained	β_7	0.024	2.346**	0.001	1.157
Distance to farm	β_8	-0.011	-1.051	-0.106	-2.863***
Banditry/herdsmen attacks	β_9	-0.009	-0.773	-0.065	-2.202**
Perceived price hike	β_{10}	0.014	1.287	-0.011	-1.454
Land ownership status	β_{11}	0.026	2.354***	-0.004	-0.477
Training in Bambara farming	β_{12}	0.031	1.741*	0.004	0.254
Off farm income	β_{13}	0.036	1.451	0.191	2.965***
McFadden's pseudo-R^2		0.917		0.937	
Log- Likelihood		329.303		447.741	
Total number of observations		360		360	

Source: Field survey data, 2024

Note: *** signifies 1% level of significance, ** signifies 5% level of significance, * signifies 10% level of significance.

The maximum likelihood estimates from the Tobit regression model for male Bambara groundnut (BG) farmers indicate that the model fits the data reasonably well. These estimates maximize the log-likelihood functions, meaning the regression coefficients (b's) maximize the joint probability (likelihood) of observing the n sample values of farmers' allocative inefficiency in the study area. This suggests that the variation in allocative inefficiency among farmers is explained by the maximum likelihood estimates of the explanatory variables,

indicating that the model accounts for significant non-zero variations in factors influencing allocative inefficiency among the male BG farmers.

Furthermore, McFadden's pseudo-R^2 is 0.917, suggesting that the model has a good fit to the data, with 91.7% of the variation in farmers' allocative inefficiency explained by the specified explanatory variables. This demonstrates the model's strong explanatory power regarding changes in allocative inefficiency among male farmers, with a 95% confidence level. The high log-likelihood value of 329.303 also suggests a better fit of the model to the data, implying that the model parameters make the observed data more probable. Given that the dependent variable represents the degree of inefficiency, a positive sign of a coefficient indicates an inverse relationship with efficiency, while a negative sign suggests a direct relationship.

The coefficients of age of farmer, level of education, farming experience, extension visits, cooperative membership, amount of credit obtained, land ownership status and training in Bambara farming are the statistically significant factors that influenced male farmers' allocative inefficiency in the study area. Age had a negative relationship with their allocative inefficiency at the 1% level of significance. This implies that as the age of male BG farmers increases, their allocative inefficiency reduces and vice versa. This aligns with Fakayode et al. (2019) and Adenuga et al. (2020). Level of education had a negative relationship with allocative inefficiency at the 5% level of significance. This indicates that higher education levels among male BG farmers are associated with reduced allocative inefficiency. This finding is consistent with Diiro (2018) and Adebayo et al. (2018). Farming experience showed a positive relationship with allocative inefficiency at the 1% level of significance. This implies that as farming experience increases, allocative inefficiency also increases among male BG farmers. This unexpected result might indicate that more experienced farmers may rely on traditional methods, which might not be as efficient as modern practices.

This finding contrasts with Yusuf et al. (2019) and Babatunde et al. (2020), who found that more experienced farmers tend to be more allocatively efficient. The coefficient of extension visits (-0.265) had a negative relationship with allocative inefficiency at the 1% level of significance. This suggests that increased extension visits contribute to reduced allocative inefficiency among male BG farmers. This finding aligns with Adeoti and Ajiboye (2019) and Olagunju et al. (2020). Cooperative membership had a positive relationship with allocative inefficiency at the 5% level of significance. This indicates that male BG farmers who are members of cooperatives tend to exhibit higher allocative inefficiency. This aligns with Oladipo and Fabiyi (2018) and Ezeh et al. (2020), who noted that poor cooperative management can lead to inefficiencies among members. The amount of credit obtained was positively related to allocative inefficiency at the 5% level of significance. This implies that male BG farmers who accessed more credit were more allocatively inefficient. This finding aligns with Amare et al. (2018) and Okoye et al. (2020). The coefficient of land ownership status (0.026) had a positive relationship with allocative inefficiency at the 1% level of significance, suggesting that male BG farmers who own land are more likely to be allocatively inefficient. Landowners may not feel the same pressure to maximize productivity as those leasing land, leading to less efficient resource utilization. This finding is consistent with Balogun et al. (2019) and Adewuyi et al. (2020). Training in Bambara farming was positively associated with allocative inefficiency at the 10% level of significance. This indicates that male BG farmers who received training in Bambara farming exhibited higher allocative inefficiency. It may be that the training was not sufficiently practical or tailored to improve resource efficiency. This finding aligns with Ayoade and Ibrahim (2016) and Olademeji et al., (2021).

For the female farmers model, the maximum likelihood estimates from the Tobit regression indicate that the model fits the data reasonably well. The McFadden's pseudo-R^2 is 0.937, suggesting that the model has a good fit to the data, with 93.7% of the variation in farmers' allocative inefficiency explained by the specified explanatory variables. This demonstrates the model's strong explanatory power regarding changes in allocative inefficiency among female farmers, with a 95% confidence level. The high log-likelihood value of 447.741 also suggests a better fit of the model to the data, implying that the model parameters make the observed data more probable.

Given that the dependent variable represents the degree of inefficiency, a positive sign of a coefficient indicates an inverse relationship with efficiency, while a negative sign suggests a direct relationship. The coefficients of age of farmer, household size, farming experience, extension visits, cooperative membership, distance to farm, banditry/herdsmen attacks, and off-farm income are the statistically significant factors that influenced female farmers' allocative inefficiency in the study area. Age had a negative relationship with their allocative inefficiency at the 5% level of significance. This implies that as the age of female BG farmers increases, their allocative inefficiency reduces and vice versa. This further suggests that older farmers tend to be more allocatively efficient due to their accumulated experience and knowledge, which helps them manage farm

operations better than younger female farmers. This finding supports the findings of Afolabi et al. (2021) and Okeke et al. (2020). Household size had a positive relationship with allocative inefficiency at the 5% level of significance. This indicates that larger household sizes among female BG farmers are associated with increased allocative inefficiency. Larger households might lead to resource misallocation as the pressure to meet household needs can reduce the focus on efficient farm management. This finding aligns with Mba et al. (2019) and Njoku et al. (2020), who noted that larger households often face challenges in resource optimization, leading to inefficiency. Farming experience showed a positive relationship with allocative inefficiency at the 1% level of significance. This implies that as farming experience increases, allocative inefficiency also increases among female BG farmers. This unexpected result suggests that experienced farmers may rely on outdated practices, leading to inefficiencies compared to less experienced farmers who might adopt newer, more efficient methods. This contrasts the findings of Oladele et al. (2019) and Adewale et al. (2020), who found that more experienced farmers were generally more allocatively efficient.

Extension visits had a positive relationship with allocative inefficiency at the 5% level of significance. This suggests that increased extension visits contributed to higher allocative inefficiency among female BG farmers. This unexpected outcome might indicate that the information provided during extension visits was either not practical or not properly applied, leading to inefficiencies. This supports the findings of Ogundele and Okoruwa (2020) and Adeyemo et al. (2021). Cooperative membership (0.086) was positively associated with allocative inefficiency at the 5% level of significance. This indicates that female BG farmers who were members of cooperatives exhibited higher allocative inefficiency. Although cooperatives are intended to enhance resource access, this result suggests that inefficiencies may arise if cooperative benefits are not properly utilized or managed. This finding aligns with Ojo et al. (2019), who noted that inefficiencies in cooperatives can sometimes lead to suboptimal outcomes for members. Distance to farm was negatively related to allocative inefficiency of female farmers at the 1% level of significance. This implies that greater distances to the farm were associated with reduced allocative inefficiency among female BG farmers. It suggests that farmers who travel longer distances may be more deliberate and efficient in planning their farm activities, maximizing productivity during the time they are present. This finding supports Nwosu et al. (2019), who observed that farmers who commute longer distances tend to plan their farm operations more carefully, leading to greater efficiency. Banditry/herdsmen attacks showed a negative relationship with allocative inefficiency at the 5% level of significance. This implies that the occurrence of banditry/herdsmen attacks was associated with reduced allocative inefficiency among female BG farmers. This counterintuitive finding might suggest that the threat of attacks forces farmers to adopt more efficient farming practices as a risk mitigation strategy. Similar findings were reported by Bala and Yusuf (2019) and Agada and Mohammed (2020), who found that adverse conditions sometimes prompt farmers to optimize their practices to minimize losses. Off-farm income was positively related to allocative inefficiency at the 1% level of significance. This indicates that female BG farmers with off-farm income sources tended to be more allocatively inefficient. This may be because off-farm income provides financial security, reducing the need for these farmers to focus intensively on maximizing farm efficiency. This finding aligns with Adebayo et al. (2021).

4. Conclusion and Recommendations

This study which focused on the determinants of allocative efficiency of male and female BG farmers in Northeast region of Nigeria has shown disparity in the level of allocative efficiency of the farmers and in the factors that influences it. Findings reveal that, generally, female farmers are more experienced in farming than their male counterparts, have larger farm sizes and marginally higher incomes from Bambara groundnut cultivation. Even with similar education levels and household sizes underpinned with these differences might impact the ways in which men and women engage in farm activities and manage resources. Female Bambara groundnut farmers are more allocatively efficient than their male counterparts in the study area. This superiority in allocative efficiency of female farmers compared to their male counterparts suggests that they are managing their resources more efficiently and hence they are more productive which leads them earn more income. The study recommends that there is need for a gender sensitive policy aimed at improving allocative efficiency, particularly through enhanced access to credit, extension services, cooperative networks, and security interventions. There is also need to develop programs that leverage the strengths of female farmers to enhance overall allocative efficiency of Bambara groundnut farmers in northeast Nigeria. Male farmers should be exposed through a collaborative workshops and training sessions to the core strategies of female farmers for efficient resource management in Bambara groundnut production. More access to production resources should be extended to female farmers in the study area to encourage them to be more efficient in the production of Bambara nut for food security.

References

2. Abdullahi, M. A., Musa, B. T., & Lawal, A. A. (2021). *Women's participation in non-farm income-generating activities and their contribution to household welfare in Northern Nigeria*. *Journal of Rural Development Studies, 13*(2), 110–122.
3. Adebayo, O. O., Adeola, A. O., & Akintunde, O. A. (2021). Education and farm efficiency: The role of literacy in modern agricultural practices. *Journal of Rural Development*, 39(2), 200–215.
4. Adegboyega, A. O., Olawoye, T., & Adekunle, F. (2021). Price volatility and its effects on agricultural productivity in Nigeria. *African Journal of Agricultural Research*, 18(4), 334–348.
5. Adenuga, A. H., Yusuf, S. A., & Ajao, A. O. (2020). Technical and allocative efficiency among arable crop farmers in Southwest Nigeria. *Journal of Agricultural Research and Development*, 19(3), 154–163.
6. Adeoti, A. I., & Ajiboye, T. S. (2019). Determinants of technical and allocative efficiency among rice farmers in Southwest Nigeria. *International Journal of Agricultural Management*, 5(3), 93–106.
7. Adewuyi, S. A., Balogun, T. A., & Bello, M. T. (2021). Effectiveness of training interventions on farm-level efficiency among cassava farmers in Nigeria. *Nigerian Journal of Agricultural Economics*, 7(3), 233–247.
8. Adzawla, W., Donkoh, S. A., Nyarko, G., Olayide, O. E., & Awai, P. E. (2023). Technical efficiency of Bambara groundnut production in Ghana. *UDS International Journal of Development*, 2(2), 37–49.
9. Afolabi, M. O., Adeola, A. O., & Akintunde, O. A. (2021). Education and farm efficiency: The role of literacy in modern agricultural practices. *Journal of Rural Development*, 39(2), 200–215.
10. Agwu, N. M., Anyanwu, C. I., & Mendie, E. I. (2018). Cooperative societies and economic efficiency among rural farmers in Nigeria. *Journal of Cooperative Studies*, 12(2), 67–78.
11. Ajani, E. N., Mgbenka, R. N., & Onah, O. (2020). *Gender roles and participation in agricultural production: A case of gender analysis in Nigeria*. *Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 20*(2), 301–308.
12. Ajilogba, C. F., Olanrewaju, O. S., & Babalola, O. O. (2022). Improving Bambara Groundnut Production: Insight Into the Role of Omics and Beneficial Bacteria. *Frontiers in Plant Science*, 13, 836133. https://doi.org/10.3389/fpls.2022.836133
13. Amare, S., Nwachukwu, C. C., & Akpan, S. B. (2018). Credit access and allocative efficiency among food crop farmers in Nigeria. *Journal of Development and AgriculturaEconomics*, 10(6), 181–192.
14. Aromolaran, A. B., Ogundele, O. O., & Adekunle, M. F. (2019). *Family labour use and food security among rural households in Nigeria*. *Nigerian Journal of Rural Sociology, 19*(1), 20–30.
15. Ayoade, A. R., & Ibrahim, S. T. (2016). Gender-sensitive training and resource efficiency among rural farmers in Nigeria. *African Journal of Rural Extension*, 9(2), 48–62.
16. Babatunde, R. O., Adebayo, T. A., & Ogunniyi, L. T. (2020). Gender dynamics and productivity differentials among crop farmers in Nigeria. *Journal of Agricultural Policy and Development*, 7(2), 101–114.
17. Balogun, O. L., Bello, T. A., & Afodu, O. J. (2019). Land tenure and farm productivity in Ogun State, Nigeria. *Ethiopian Journal of Environmental Studies & Management*, 12(3), 315–324.
18. Bello, A. S., Lawal, R. A., & Okoye, M. T. (2022). *Credit utilization and its effect on farm-level efficiency in the Nigerian agricultural sector*. *Journal of Development Economics, 13*(5), 189–202.
19. Berchie, J. N., Adu-Dapaah, H. K., Dankyi, A. A., Plahar, W. A., Nelson-Quartey, F., Haleegoah, J., Asafu-Agyei, J. N., & Addo, J. K. (2010). Practices and constraints in Bambara groundnut production, marketing, and consumption in Ghana. *Journal of Agronomy, 9(3),* 111–118.
20. Dagachi, M., & Olorunsanya, E. O. (2023). Technical Efficiency of Bambara Nut Production in Niger State, Nigeria. *Journal of Agripreneurship and Sustainable Development*, 6(1), 56–64. https://doi.org/10.59331/jasd.v6i1.392
21. Degefa, T., Jaleta, M., & Legesse, G. (2017). Estimating technical, allocative, and economic efficiencies of wheat production in Ethiopia. *African Journal of Agricultural and Resource Economics*, *12*(2), 107–119.
22. Diiro, G. M. (2018). Impact of education on allocative efficiency in smallholder agriculture: Evidence from Uganda. *International Journal of Education and Development*, 4(2), 88–101.
23. Ezeh, C. C., Nwachukwu, C. A., & Nwafor, E. U. (2020). Resource-use inefficiencies in farmer cooperatives: A study of Southeastern Nigeria. *African Journal of Economic Policy*, 25(1), 112–130.
24. Fakayode, S. B., Babatunde, R. O., & Ajao, R. (2019). Productivity analysis of cassava-based production systems in the Guinea Savannah: A case study of Kwara State, Nigeria. *American-Eurasian Journal of Scientific Research*, 3(1), 33–39.
25. FAO. (2021). The status of women in agrifood systems. *Food and Agriculture Organization of the United Nations*. https://www.fao.org
26. Farrell, M. J. (1957). The measurement of productive efficiency. *Journal of the Royal Statistical Society: Series A (General)*, *120*(3), 253–290. https://doi.org/10.2307/2343100
27. Godwin, A. A., & Moses, O. E. (2014). Bambara groundnut/maize intercropping: Effects of planting densities in Southern guinea savanna of Nigeria. *African Journal of Agricultural Research*, *9*(4), 479–486. https://doi.org/10.5897/ajar2013.7955

28. Greene, W. H. (2000). *Econometric analysis* (4th ed.). Prentice Hall.
29. Henry, G. G., Idi, S., & Abdullahi, S. (2023). Analysis of Poverty Status among Farming Households in Central Zone of Plateau State, Nigeria. *Journal of Agripreneurship and Sustainable Development*, 6(2), 78–88. https://doi.org/10.59331/jasd.v6i2.436
30. Ibeawuchi, C. O., Ezeh, K. U., & Chukwu, M. E. (2023). Assessing intervention outcomes on agricultural productivity: Evidence from community-driven development programs in Southeast Nigeria. *African Journal of Rural Development*, 15(1), 112–126.
31. Ibrahim, B. A., & Aluko, S. (2021). *Examining the link between farming experience and efficiency in crop production*. *Journal of Agricultural Management, 19*(3), 277–290.
32. Majola, N. G., Gerrano, A. S., & Shimelis, H. (2021). Bambara Groundnut (Vigna subterranea [L.] Verdc.) Production, Utilisation and Genetic Improvement in Sub-Saharan Africa. *Agronomy*, *11*(7), 1345. https://doi.org/10.3390/agronomy11071345
33. Mohammed, T., & Ather, M. A. (2020). Measuring total factor productivity and its determinants at sectoral level: A case study of Pakistan. *Industrial Engineering Letters*, 5(6), 38–53.
34. Mohammed, U. A., Yusuf, A. O., & Sani, M. M. (2022). *Determinants of income inequality among crop farmers in rural Nigeria*. *African Journal of Agricultural Research, 17*(6), 889–899.
35. Nafula, W. C., Masinde, I. T., Otieno, O. D., & Wafula, W. V. (2021). Incidence and severity of Fusarium wilt on Bambara nut (Vigna subterranea L.) landraces in Western Kenya. *African Journal of Biological Sciences*, *3*(1), 67–75. https://doi.org/10.33472/afjbs.3.1.2021.67-75
36. Okeke, C. O., Chijioke, M. U., & Ogbuagu, B. C. (2020). Impact of agricultural extension services on farm-level efficiency. *International Journal of Agricultural Extension and Rural Development*, 12(4), 278–289.
37. Okoye, B. C., Ukoha, O. O., & Onyenweaku, C. E. (2020). Influence of credit on farm efficiency in cassava production: A stochastic frontier analysis. *Nigerian Agricultural Journal*, 51(2), 98–107.
38. Oladejo, J. A., Akinbile, L. A., & Kolade, A. I. (2019). *Socioeconomic characteristics influencing farming households' decision to engage in cooperative societies in Osun State, Nigeria*. *Journal of Agricultural Extension, 23*(4), 45–57.
39. Oladimeji, Y. U., & Abdulsalam, A. (2019). Impact of extension services on allocative efficiency of female farmers in Kwara State, Nigeria. *Journal of Extension Systems*, 35(1), 42–55.
40. Oladimeji, Y. U., Offokansi, C. C., & Egwuma, H. (2021). Analysis of economic efficiency and its determinants in millet-based production systems in Nigeria. *Alanya Academic Review*, 5(1), 177–192.
41. Oladipo, M. O., & Fabiyi, Y. L. (2018). Evaluating cooperative effectiveness in promoting farm-level resource use. *Nigerian Journal of Development Studies*, 18(2), 77–90.
42. Olagunju, F. I., Akinbode, S. O., & Ajayi, O. M. (2020). Efficiency analysis of smallholder maize farmers: Implications for cooperative interventions. *Journal of Cooperative Studies*, 25(4), 211–225.
43. Olayide, S., Ho, W. K., Chai, H. H., & Massawe, F. (2022). Bambara groundnut: An exemplar underutilized crop for resilience under climate change. *Planta*, 250(3), 803–820.
44. Onu, J. I., & Abba, A. (2020). Gender-based differences in farm efficiency: Evidence from maize production in Northern Nigeria. *Journal of Agricultural Economics and Extension*, 10(4), 87–102.
45. Tan, X. L., Azam-Ali, S., Goh, E. V., Mustafa, M., Chai, H. H., Ho, W. K., Mayes, S., Mabhaudhi, T., Azam-Ali, S., & Massawe, F. (2020). Bambara Groundnut: An Underutilized Leguminous Crop for Global Food Security and Nutrition. *Frontiers in Nutrition*, *7*(1). https://doi.org/10.3389/fnut.2020.601496
46. Temegne, N. C., Patrice, J., Nbendah, P., Ntsomboh-Ntsefong, G., Taffouo, V. D., & Youmbi, E. (2020). Cultivation and Utilization of Bambara Groundnut (Vigna subterranea (L.) Verdc.), a Neglected Plant in Cameroon. *Asian Plant Research Journal*, 9–21. https://doi.org/10.9734/aprj/2020/v4i230081
47. Tobin, J. (1958). Estimation of relationships for limited dependent variables. *Econometrica*, *26*(1), 24–36. https://doi.org/10.2307/1907382
48. Umar, H. O., Yusuf, H. A., & Shuaibu, H. (2022). Analysis of production efficiency among small-scale soybean farmers in Sabon Gari Local Government Area of Kaduna State, Nigeria. *International Journal of Agriculstural Economics, Management and Development*, 8, 195–205.
49. World Bank. (2023). *Agricultural sector contribution to GDP and rural employment in Nigeria.*
50. Yohannis, T. (2020). Technical of Agricultural Production in Ethiopia. *Journal of Natural Sciences Research*, 10(4), 112–123.
51. Yusuf, H. O., Omokore, D. F., & Olawoye, R. (2019). Farm-level efficiency and gender analysis among maize farmers in Kaduna State. *African Journal of Agricultural Research*, 14(11), 636–644.
52. Yusuf, H. O., Omokore, D. F., Olawoye, R., Yusuf, H. A., & Shuaibu, H. (2022). Analysis of production efficiency among small-scale soybean farmers in Sabon Gari Local Government Area of Kaduna State, Nigeria. *International Journal of Agricultural Economics, Management and Development,* 8, 195–205.