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Technical Efficiency of Onion Farmers in Taraba State, Nigeria

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ABSTRACT
Onion production is an important source of food, income, and employment for many rural households in Nigeria. Despite its economic importance, productivity among smallholder onion farmers remains below potential due to technical inefficiency in the use of available production resources. This study examined the technical efficiency of onion farmers in Taraba State, Nigeria. Primary data were collected from 254 onion farmers using a structured questionnaire and analyzed using descriptive statistics and the stochastic frontier production model. The results revealed that the respondents were relatively young and economically active, with a mean age of 38 years, an average household size of 6 persons, and an average farming experience of 10 years. The estimated mean technical efficiency was 0.658, indicating that farmers achieved only 65.8% of the potential output, leaving room for a 34.2% improvement through more efficient use of existing resources. The estimated sigma-square value (0.0027) was statistically significant, confirming the suitability of the stochastic frontier model, while lambda value (2.23298) indicated that the differences between observed and potential output were mainly due to technical inefficiency. The gamma estimate of 0.83 further showed that 83% of the variation in onion output was attributable to technical inefficiency. Education, farming experience and age significantly improved farmers' technical efficiency, whereas limited access to extension services and credit reduced efficiency. The study concludes that onion production in Taraba State has considerable potential for increased productivity through improved resource-use efficiency. It recommends strengthening extension services, improving farmers' access to quality inputs and affordable credit, promoting farmer cooperatives, and encouraging the adoption of improved onion production technologies.

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INTRODUCTION

Onion (*Allium cepa L.*) is a vegetable crop used extensively in preparing condiments, sauces, stews and soups. Onions are an excellent cheap, long-lasting and rich source of micronutrients and play a vital role in ensuring good health (Olanrewaju et al., 2021). Onions and other vegetables play a vital role in Sub-Saharan Africa, offering low-cost, reliable supplies of protein, vitamins, zinc and iron (Osei et al., 2017; Robert et al., 2021).

According to the Food and Agriculture Organization (FAO, 2020), Onion cultivation is an agricultural activity that is widely practiced in the world, with an estimated area of 5.4 million hectares and an estimated production of 104.5 million tons per year. China, India, US, Egypt, and Turkey are the top five onion-producing nations in the world. According to data released by the Food and Agriculture Organization, India has the most vast onion crop area of 1.4 million hectares followed by China with 1.08 million hectares. India is the leading producer of onions with a production of 26.7 million tons and China is second with 23.7 million tons. The Republic of Korea has the highest productivity of onions in the world at 79.61 tons per hectare, followed by Australia, at 54.66 tons per hectare, Spain at 52.10 tons per hectare and Japan at 49.31 tons per hectare.

Onion cultivation in Nigeria has significant socio-economic contribution. Nigeria is one of the leading onion-producing nations in Africa with an estimated 1,550 MT of dry onions produced in 2022 (FAO, 2024). In the same year, according to the production records of FAOSTAT, the production of onions and shallots (green) was 243,381 tons from 14,132 hectares, with an average yield of 17.22 tons per hectare (FAO, 2024). The production of onions is therefore increasing in Nigeria with a major contribution from the smallholder farmers.

Vegetables like onions, tomatoes, okra, pepper, and cabbages are grown extensively along the river banks that traverse the villages, towns and cities. The farming activity is mainly conducted by small-scale farmers (Robert et al., 2021). This practice is an old one in Nigeria and in Taraba State; it has been a source of employment and income to the farmers especially during the dry season.

Onion production in Taraba State has a high economic value, but there have been much fluctuations in the production. The state had the highest production of 323 thousand tons in 2017. In this year 63 thousand hectares were planted and the average crop size was 5.13 tons per hectare. But in 2018, the production was 126 thousand tons while the number of hectares under cultivation had grown to 78 thousand, and the yield had fallen to 1.62 tons per hectare. In 2019, production was increased to 376 thousand tons and the yield to 6.59 tons/ha in the 57 thousand hectares of cultivated area. However, in 2020, the production was again reduced to 276 thousand tons, average yield to 4.18 tons/ha and increased area of cultivation by 66 thousand ha (TADP, 2021). The ups and downs illustrate the difficulties of the onion farmers in Taraba State. To overcome these issues, onion production needs to be stabilized and increased to meet the demand, which is essential for improving the livelihoods of the smallholder farmers and providing a continuous supply of onions.

Several factors are responsible for the poor production of vegetable in Africa, in particular in Taraba state of Nigeria, such as limited resources, resource inefficiency and socio-economic and agricultural factors as argued by Osei et al (2017) cited in Robert et al (2021). With the low fertility of the soil, the use of agrochemicals to overcome production constraints is worsening these challenges in the context of onion production. The use of traditional crop varieties has been replaced by high-yielding improved varieties, which require large inputs of nutrients (Laary, 2014). Insect pests are especially a problem on onion crops as they feed and breed on the crop. This puts the farmers under pressure to have to spray on their crops with agrochemicals like insecticide, herbicide and fertilizer to protect their crops from insects, pests and diseases. The quality of onions starts to deteriorate immediately after harvest and continues until they are consumed, making onion production a high-risk endeavour.

Onion cultivation is risky, and there are several factors out of the farmer's control. Onion yield is influenced by biotic and abiotic conditions of plant development, pest and disease incidence and weather such as drought and flood. Moreover, the market dynamics like abrupt changes in input prices and output prices have enormous risks (Kara et al., 2019). Onions are also perishable, adding another layer of difficulty to maintaining a balance between supply and market demand. The perishable nature of onions also makes it challenging to coordinate supply and market demand, creating potential losses and inefficiencies along the supply chain. Solving these problems takes a comprehensive approach, ranging from better resource management to better access to agricultural inputs to effective pest and disease control measures. Improving the soil fertility by sustainable management and strengthening market linkages can help in stabilizing the onion production and secure farmers' income.

Studies on the efficiency have been identified as important approaches for improving the farm income of farmers and their economic status to achieve high production of onions. This has led to the large number of output-enhancing programmes, policies and initiatives being adopted by various government and non-government organizations. There are a number of options of increasing output, in theory, including increasing the area of land used to produce onions, using higher yielding varieties of onions, and reorganizing existing factors of production to produce a given amount of onions with fewer resources. But due to the pressure of urbanization, industrialization and competing land use, it is becoming difficult to expand the onion cultivation area. Therefore, an understanding of the technical efficiency in onion production becomes of much importance. This knowledge can uncover how to get the most out of a yield and limit potential costs.

The technical efficiency evaluation of the farm can help the farmers and policy makers to evaluate the current practices on the farm and take measures to optimize the utilization of resources. Examples of this include better crop management practices, pest & disease management practices and fertilizer use. Thus, this study was designed to analyze the socio-economic characteristics of onion farmers, estimate the technical efficiency levels of onion farmers, identify the socio-economic and institutional factors affecting technical inefficiency in the study area.

MATERIALS AND METHODS

The Study Area

The study was conducted in Taraba State, Nigeria. Taraba State is located in the north eastern part of Nigeria. It lies between latitude6° 34'36"and 9° 58'51" North of the equator and between longitude 9° 00' and 12° 00'East of the Greenwich Meridian. The State is geographically positioned with its northern borders touching Bauchi and Gombe States. To the east, it is bordered by Adamawa State, while the southern boundary extends to the Republic of Cameroon. On its western side, Taraba State is adjacent to Plateau, Nassarawa, and Benue States, covering a land area of approximately 60,291 square kilometers (23,271 square miles). The state has an estimated population of approximately 2.5 million people (NPC, 2006) with a projected population of 4,407,320 as at August, 2024 on a projection rate of 3.2% as recommended by National Population Commission. The state's diverse geographical neighbours and significant land area contribute to its strategic importance in the region. The State is referred to as "Nature's Gift to the Nation" due to its rich natural resources. The state boasts a wealth of solid mineral resources, plentiful surface water, and extensive arable and grazing lands. Agriculture is the primary occupation of the residents, supported by the state's diverse climate and vegetation, which mirror the country's range from the humid, forested southern regions to the seasonal wet and dry climates with savannah vegetation in the north. This favourable environment allows for the cultivation of various vegetables like onion, okra, tomato, cucumber, spinach, and pepper. Tree crops, including palm trees, bananas, plantains, oranges, cashews, guavas, and mangoes. Root crops such as cassava, potatoes, and yams thrive here, as do cereals like maize, millet, rice, and guinea corn. The state's agricultural portfolio also includes cash crops such as coffee, tea, cocoa, and groundnuts.

Sampling Techniques and Sample Size

A multistage sampling procedure was employed to select onion farmers in Taraba State. Stage I: Two Local Government Areas (Jalingo and Ardo-Kola) were purposively selected from Zone I, and one Local Government Area (Wukari) was selected from Zone II. These locations were chosen based on their relatively high level of dry season onion production compared to other areas within the state. Stage II: Using the snowball, a total of 752 onion farmers were identified across eleven major onion-producing communities, namely: (Ardo-Kola:PantiTugang, Mallam Hayatu, Kantilye), (Jalingo:Water Board, Magami, Babadidi, Nukai), and (Wukari:Arufu, Ndo-Katswen, Chinkai, and Tsukondi). Sample size was determined using Yamane (1967) as cited in Danji *et al.* (2025), by the formula

$$n = \frac{N}{1 + N(e)^2} \quad (1)$$

Where: n = sample size, N = population size, and e = margin error at 5% $(0.05)^2$

Thus, $n = \frac{752}{1 + 752\ (0.05)2} = 261$

Table 2: Sample Design Outlay for the Study Area

S/N	Blocks	Farming cells	Estimated Population of onion farmers	Sample size of the onion farmers
Zone I	Ardo-kola	Panti tugang	85	30
		Mallam hayatu	59	20
		Kantilye	41	14
	Jalingo	Water board	123	43
		Magami	88	31
		Babadidi	72	25
		Nukai	53	18
Zone II	Wukari	Arufu	82	28
		Ndo-katswen	49	17
		Chinkai	54	19
		Tsukondi	46	16
Total	3	11	752	261

Source: Field survey, 2025.

Sources and Methods of Data Collection

Primary data were obtained from respondents using questionnaire. The questionnaire covered socioeconomic information from farmers such as age, marital status, educational level, farming experience, family size, and access to extension services. The questionnaire also captured the amount of output received. Other information includes the size of the farm, membership or otherwise of the Onion Farmers Association, and how the farms were cultivated, planted, and harvested. The questionnaires were administered by the researcher, with the help of research assistants.

Methods of Data Analysis

Descriptive statistics such as frequency counts, percentages, mean, minimum and maximum values and standard deviation were used to describe the socio-economic characteristics of the respondents. The research also adopted the stochastic frontier technique by using the single-stage maximum likelihood estimation available in the Stata 14 software.

Model specification

Cobb-Douglas frontier production function used in the study is explicitly specified as:

$$ln\, ln\,(Yi)\; = \beta 0 + ln\, \beta_1 ln\,(X_{1i})\; + \beta_2\, ln\, ln\,(X_{2i})\; + ln\, \beta_3 ln\,(X_{3i})\; + ln\, \beta_4 ln\,(X_{4i})\; + \,Vij - Uij \qquad (2)$$

Where: Ln = the natural logarithms to be estimated, Yi = Output of onion from farm i measured in kilogram per hectare (Kg/ha), β_0 = constant term, $\beta_1 - \beta_4$ = Maximum Likelihood Estimate (MLE) coefficients, and X_1 = Seed used (kg)/ha, X_2 = Fertilizer used (kg)/ha, X_3 = Agrochemicals used (Litre)/ha, X4 = Labour input (Man-hour)/ha. V = statistically disturbance term like measurement error and external sources out of the farmer's control.

$$U_{ij} = \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 + \delta_6 Z_6 + \delta_7 Z_7 + \delta_8 Z_8 + \delta_9 Z_9 \qquad (3)$$

Where; U_{ij} = Technical inefficiency of the ith farmer, δ_{1} - δ_9 = Parameters to be estimated, Z_1 = Age of the farmer (years), Z_2 = Household size (number of persons in household), Z_3 = Educational level (Never been to school = 0, primary = 1, secondary = 2 Diploma/NCE = 3, Degree and above = 4), Z_4 = Farming experience (years), Z_5 = Extension contact (1=had contact, 0= otherwise), Z_6= Land cultivation (1= used machine, 0= used manual, Z_7 = Planting technique (1 if machine is used for planting method, otherwise 0), Z_8 = Credit access (₦), Z_9 = Membership in a Farm-Based Organization (1 = member, 0 = non-member)

RESULTS AND DISCUSSION

Summary Statistics of Output and Input Variables for the Mean and Variance Function Analysis

The summary statistics of the variables used for the mean and variance function analysis are presented in Table 3. The results show that the average onion output obtained from the surveyed farms was 2,921.12 kg/ha (≈ 2.9 t/ha). The yield among the farmers ranged from a minimum of 1400 kg/ha to a maximum of 4890 kg/ha, with a standard deviation of 528.686 kg/ha. This relatively wide range in output indicates considerable variation in the productivity of onion farmers within the study area. Such variation may be attributed to differences in the quantity and quality of inputs used, production practices, and the level of farmers' technical efficiency.

With respect to input use, the average quantity of seed utilized by the farmers was 5.12 kg/ha, with the lowest and highest seed application rates recorded at 3.00 kg/ha and 9.00 kg/ha, respectively. The computed standard deviation of 1.42 kg/ha suggests moderate variability in seed usage among the farmers. This indicates inconsistency in seed application among farmers, which may lead to uneven plant population and sub-optimal yield performance. Standardizing seed rates through improved extension guidance and access to quality seed could enhance productivity and production efficiency.

In terms of fertilizer use, the average rate of fertilizer application among the sampled farmers was 182.60 kg/ha, ranging between 120 kg/ha and 240 kg/ha, with a standard deviation of 32.75 kg/ha. The relatively high variation observed indicates that farmers differ considerably in their fertilizer application practices. This may be linked to factors such as resource availability, access to extension services, and farmers' knowledge of soil fertility requirements. The result further revealed that the average quantity of agrochemicals used in onion production was 4.38 litres/ha, with a minimum of 2.00 litres/ha and a maximum of 8.00 litres/ha, and a standard deviation of 1.21 litres/ha. The relatively low variation in agrochemical use suggests a fairly uniform pattern of pest and disease management among farmers, compared with other inputs.

Labour input was found to be 78.25 man-days/ha on average, with a minimum of 60 man-days/ha, and a maximum of 95 man-days/ha, while the standard deviation was 9.14 man-days/ha. This high labour requirement highlights the labour-intensive nature of onion production, especially in smallholder farming systems where mechanization is limited. The variation in labour use could be attributed to differences in household labour endowment, the use of hired labour, and the intensity of farm operations such as land preparation, weeding, irrigation, and harvesting.

Table 3: Summary Statistics of output and input variables for the Mean and Variance Function Analysis

Variable	Unit	Mean	Minimum	Maximum	Std. Dev.
Output					
Onion bulb	Kg/ha	2921.12	1400	4890	528.686
Inputs					
Seed	Kg/ha	5.12	3.00	9.00	1.42
Fertilizer	Kg/ha	182.60	120	240	32.75
Agro-chemicals	L/ha	4.38	2	8.00	1.21
Labour	Man-day/ha	78.25	60	95	9.14

Source: Field Survey, 2025.

Socio-economic Characteristics of the Respondents
Age, sex, marital status, number of people in the household, size of the farm, level of education, farming experience, contact with an extension officer, method of land cultivation, and method of planting were all taken into account.

Age of the Respondents
Age refers to the stage of an individual's biological and socio-economic development and plays an important role in shaping farming behaviour, experience, and managerial ability. In this study, age was measured in years and is expected to influence farmers' decision-making capacity, openness to innovation, and overall farm performance. Table 4 presents the age distribution of onion farmers in the study area. The results show that the mean age of the respondents was 38 years, with ages ranging from 18 to 64 years and a standard deviation of 10.5 years. The mean age indicates that onion production in the study area is largely carried out by farmers who are within their economically active years. Farmers in this age group generally possess the physical strength required for labour-intensive activities such as land preparation, transplanting, irrigation, and harvesting, which are central to onion cultivation. In addition to physical capacity, they are likely to have accumulated sufficient farming experience to make informed production decisions and manage farm resources effectively. From an efficiency perspective, farmers within this productive age bracket are often more willing to adopt improved production technologies and management practices (Kara et al., 2019). Their ability to combine experience with a readiness to try new ideas, such as improved seed varieties or better input management practices, can help reduce production inefficiencies. Compared to much older farmers, they may also be more willing to take risks in pursuit of higher output and profitability, which can positively influence technical efficiency.
The variation in age among respondents further suggests the presence of both younger and older farmers in onion production. While younger farmers contribute energy and innovation, older farmers bring valuable experiential knowledge gained over years of farming. This combination supports learning and knowledge transfer within farming households and communities, which may enhance production efficiency. Consequently, age is expected to be an important factor explaining differences in technical efficiency among onion farmers and is therefore included in the inefficiency effects model estimated later in this study. This finding is consistent with Yidau et al. (2020), who reported a mean age of 41 years among onion farmers in Southern Adamawa State, Nigeria. It also aligns with Morgan *et al.* (2021), who found that the majority of vegetable farmers in Yenagoa Local Government Area of Bayelsa State were between 20 and 39 years of age, as well as Tahir *et al.* (2022), who highlighted the active participation of young and middle-aged farmers in vegetable production systems in Hawul Local Government Area of Borno State.

Table 4: Distribution of the Respondents according to Quantitative Socio-economic Characteristics

Variable	Mean	Minimum	Maximum	Std. Dev.
Age	38	18	64	10.5
Household size	6	1	20	3.94
Farming exp.	10	1	41	6.99
Farm size	1.5	0.4	3.2	0.75

Source: Field survey, 2025.

Household Size of the Respondents
Household size refers to the number of individuals living together and sharing meals within a household. It is an important socio-economic characteristic in smallholder farming because it directly affects labour availability, household expenditure, and farm management decisions. In this study, household size was measured as the number of persons per household. The results in Table 4 showed that the respondents had a mean household size of 6 persons, with household sizes ranging from 1 to 20 persons. The relatively large household size observed among onion farmers suggests that most households have access to family labour for farm operations. Onion production is labour-intensive, requiring careful and timely activities such as transplanting, weeding, irrigation, and harvesting. Having family members who can contribute labour reduces farmers' reliance on hired labour, lowers production costs, and allows farm operations to be carried out at the appropriate time. These factors can enhance farmers' ability to use available inputs efficiently and operate closer to the production frontier.
The variation in household size among respondents suggests that efficiency outcomes are likely to differ across farm households. This makes household size a relevant variable in explaining differences in technical efficiency among onion farmers. The finding is consistent with Haile (2015), who found an average family size of 6 persons among onion producers in irrigated agriculture in Kobo District, Ethiopia, and highlighted household size as an important factor

influencing efficiency. Similarly, Sunday and Monday (2021), reported an average household size of 6 persons among farming households in the South–South region of Nigeria.

Farming Experience

Farming experience refers to the number of years a farmer has been engaged in onion production. Experience is widely regarded as an important factor influencing farm efficiency, as it enhances farmers' understanding of local agro-climatic conditions, improves managerial skills, and supports better production decisions (Oluwatayo et al., 2008). Table 4 presents the distribution of farming experience among onion farmers in the study area. The results show that respondents had an average of 10 years of farming experience, with experience ranging from 1 to 41 years and a standard deviation of 6.99 years. The average level of experience observed suggests that most farmers have acquired considerable practical knowledge of onion production over time. Through repeated production cycles, farmers learn how to manage critical farm operations such as land preparation, input application, pest and disease control, and irrigation scheduling. This accumulated knowledge enables them to anticipate production challenges and respond more effectively, thereby improving farm performance.

From a technical efficiency perspective, experienced farmers are generally better positioned to use available inputs in optimal combinations and to minimize wastage arising from poor timing or inappropriate input use. Experience also enhances farmers' ability to interpret extension advice and adapt recommended technologies to local conditions. Consequently, increased farming experience is expected to reduce technical inefficiency and contribute positively to productivity in onion production. However, the wide variation in years of experience among respondents indicates the coexistence of relatively new entrants and highly experienced farmers in the study area. While newer farmers may bring innovation and openness to improved practices, more experienced farmers contribute valuable knowledge gained over years of farming. This mix can foster learning and gradual improvement in production efficiency within farming communities. Basically, the observed level of farming experience among respondents presents a favourable condition for achieving higher productivity and efficiency in onion farming. The finding is consistent with Alabi et al. (2023), who reported that the majority (82%) of vegetable farmers had between 1 and 10 years of farming experience. Similarly, Emmanuel et al. (2024) found that 61.7% of onion farmers in the Western Agricultural Zone of Bauchi State, Nigeria had farming experience ranging from 1 to 10 years, highlighting the relevance of experience in vegetable production systems.

Farm Size

Farm size refers to the total area of land cultivated for onion production by a farmer and is an important factor influencing production scale, input use, and farm management decisions. In this study, farm size was measured in hectares. The results in Table 4 showed that the mean farm size cultivated by the respondents was 1.5 hectares, with farm sizes ranging from 0.4 to 3.2 hectares and a standard deviation of 0.75 hectares. The average farm size indicates that onion farming in Taraba State is predominantly practiced on a small to medium scale basis. This pattern reflects the prevailing land tenure system, population pressure on land, and limited access to capital, which characterize most rural farming communities in Nigeria. Small farm holdings often restrict the expansion of cultivated area and limit the ability of farmers to benefit from economies of scale, particularly in relation to mechanization and bulk input purchase. Despite these limitations, smaller farm sizes may offer certain managerial advantages. Small and medium scale farms are generally easier to supervise, allowing farmers to closely monitor crop growth and respond promptly to issues such as pest infestation, nutrient deficiencies, and water stress. This close management can encourage more intensive cultivation practices and efficient use of inputs, which may partly offset the disadvantages associated with limited farm size. However, the constrained land area may still limit total output and farm income, even when production is relatively efficient.

From an efficiency perspective, farm size may influence technical efficiency in different ways. While larger farms may enjoy scale advantages, smaller farms may achieve higher efficiency through intensive management and better control of production activities. The variation in farm sizes observed among respondents, therefore, provides useful insight into differences in productivity and efficiency levels among onion farmers in the study area. The finding agreed with Tahir *et al.* (2022), who reported that 62.75% of respondents operated small-scale farms ranging from 0.1 to 1 hectare. Similarly, Emmanuel *et al.* (2024) found that the majority (89.6%) of onion farmers in the Western Agricultural Zone of Bauchi State, Nigeria, cultivated farm sizes between 1 and 4 hectares, further highlighting the dominance of smallholder farming systems in onion production across similar agro-ecological settings.

The Sex of the Respondents

Sex mainly describes the biological distinction between males and females, and it usually shapes how people take part and what kind of roles they have in agricultural activities. Farming is commonly seen as a very physical and strenuous work, so it needs a lot of effort, like for land preparation, planting, weeding, and then harvesting. Because of this, men are often seen doing the more intense field operations, but women often get involved in related work such as processing, marketing, and post-harvest handling. And honestly, those tasks are just as important for farm productivity and also for household food security (Kara et al., 2019).

Looking at Table 5 the results show that most, about 88.6% of the onion farmers sampled, were male. This points to the idea that men-controlled onion production in the study area. The same pattern was also mentioned by Abdu et al. (2015), who said 92.5% of the onion farmers in the Hadejia Valley Irrigation Project, Jigawa State, Nigeria, were male. On the other hand, Mulaudzi (2017) in Vhembe District, Limpopo Province, South Africa, and Morgan et al. (2021) in Yenagoa Local Government Area, Bayelsa State, Nigeria, reported something different, where women were the major players in onion cultivation in those places.

So, these differences really show how socio-cultural, economic, and environmental factors can influence gender roles in agriculture. In short, even if men are more visible in the field side, the women contributions, through supporting roles and value-adding activities, are still crucial for overall farm outputs and household well-being.

Table 5: Distribution of the Respondents according to Qualitative Socio-economic Characteristics

Variable	Frequency	Percentage
Sex		
Male	225	88.6
Female	29	11.4
Marital status		
Married	223	87.8
Single	31	12.2
Educational level		
No formal education	97	38.2
Primary school	31	12.2
Junior secondary school	41	16.1
Senior secondary school	36	14.2
Tertiary level	49	19.3
Membership of cooperative society		
Member	165	65.0
Non-member	89	35.0
Extension contact		
Had contact	67	26.4
Had no contact	187	73.6
Land acquisition		
Inheritance	75	29.5
Purchase	63	24.8
Hired	116	45.7
Cultivation method		
Manual	212	83.5
Machine	42	16.5
Planting method		
Transplanting	254	100.0
Harvesting method		
Manual	254	100.0
Total	254	100.0

Source: Field survey, 2025.

Marital Status of the Respondents

Table 5 shows the marital status of the respondents. The results reflect that 87.8% of the respondents were married, whereas 12.2% were single. This indicates that most of the onion farming in the study area is done by people with established households, who may bring more stability, commitment, and seriousness to farm management. Farmers who are married often consider agriculture as their main source of livelihood, and are driven by the needs of the family, as well as food security. The result is consistent with Sunday and Monday (2021) who found that 74% of the onion farmers in the South-South region of Nigeria were married, pointing to the importance of family in the continuance of farming activities. Likewise, *Emmanuel et al*. (2024) discovered that 75.6% of their respondents in Bauchi State were married, a sign of the widespread prevalence of male-headed households and the family-based farming systems in Nigeria.

Educational level of the Respondents

Education is one of the most important factors influencing farmers' ability to adopt new technologies, make informed decisions, and increase productivity. Generally, farmers with higher levels of education have a better capacity to understand, assess, and carry out innovative practices, which can result in better production outcomes. The information in Table 5 shows that 38.2% of the respondents were illiterate, 12.2% had primary education, 16.1% completed junior secondary, 14.2% finished senior secondary, and 19.3% had tertiary education. The majority of respondents (61.8%) had one or more levels of formal education. This means that they most likely have the skills to search for information, communicate well, and go for enhanced agricultural methods. The results are not surprising; Akanlik (2020) reported that 74.63% of farmers in Ghana's Upper East Region were literate to one year of schooling or more. Likewise, Danji et al. (2025) discovered that 78.7% of onion farmers in Wukari Local Government Area had some type of formal education. Hassan et al. (2025) even stated that a significant number of farmers had gone on to get tertiary education (53.3%).Being educated gives farmers knowledge as well as the courage to carry out new methods, to change along with the environment, and to be willing to engage in projects that lead to better farm results.

Membership of Cooperative Society

Cooperative societies are kind of formal organization set up, to push collective interests, handle shared difficulties, and try to reach aims that, for individuals, can be hard to manage alone. In agriculture, these cooperatives do a lot more than just “meeting”, they support farmers by easing access to important things like farm inputs, credit options, workable markets, and also technical information. They further work as a place where new ideas are passed around, and better farming methods are introduced, which can raise productivity and also efficiency (Chikezie et al., 2012). Farmers that join cooperative societies are generally more willing to take up new technologies and innovations than farmers working on their own. Since membership creates a chance for experience exchange, group-based solution building, and synchronized choices, it can lower production bottlenecks and help farm management run better. From the results shown in Table 5, it was clear that most of the respondents (65.0%) were members of cooperative organizations, while 35.0% were not part of any cooperative. This relatively high cooperative participation level indicates that many onion farmers in the area of study likely gain from improved access to agricultural information, essential inputs, and supportive networks. Moreover, being inside a cooperative can nudge farmers to take up good practices earlier, and it may also help them use resources in a more organized way. As a result, there is a stronger chance of realizing better yields. These outcomes align with Kolade and Harpham (2014), who concluded that cooperative membership improves farmers' reach to useful productive resources and increases the odds that improved agricultural technologies will be adopted. So, the bigger point here is that cooperative membership does not only build farmers' ability to manage their farms properly, it also brings a shared feeling of responsibility, and that sense can help farmers face challenges that might be overwhelming if handled separately. In relation to onion production, it therefore looks like cooperative involvement could be an important driver of both technical efficiency and the overall performance of the farm.

Extension Contact

Extension services play a crucial role in agricultural development because they give farmers timely information, some technical guidance, and practical support for switching to improved farming practices (Mulaudzi, 2017). When farmers have regular interaction with extension agents they're more likely to run into innovations, newer technologies, and good farming approaches, which can raise productivity, reduce production bottlenecks, and generally make the farm run better. So, the frequency and the quality of these interactions really matter, because they help determine technology uptake and overall performance in farming systems (Sarker et al., 2017). Looking at Table 5, the results indicate that most respondents, 73.6%, did not have any contact with extension agents, while only 26.4% said they had contact with them. This kind of low engagement may affect farmer's awareness and their ability to adopt improved onion production technologies, and that can lower technical efficiency as well as yield outcomes. Also, the limited routine guidance and the weak access to recent information can make it hard for farmers to apply best practices properly, especially for things like pest control, fertilization, and irrigation.

This outcome differs from Akanlik (2020), who found that 85.66% of farmers in Ghana's Upper East Region had access to extension services, basically pointing out regional differences in advisory support. Likewise, Olanrewaju et al. (2021) reported that in Lagelu Local Government Area, more than half of both male (65.4%) and female (52.4%) farmers had no contact with extension agents, which suggest persistent difficulties in reaching farmers in certain places. Overall, the low level of extension contact in this study area suggests a clear need for specific actions, not just general ones, to boost information circulation, encourage farmers to adopt technologies, and back them in improving their productivity. By strengthening extension services, increasing field visits, and supporting farmer training sessions, it could improve innovation uptake, help farmers use resources more efficiently, and in the end raise the technical efficiency of onion production in the study area.

Mode of Land Acquisition

Land acquisition in agriculture covers not only the purchase of ownership rights but also the taking hold of user rights, such as via leases, concessions, or inheritance, whether it is short lived or long term (Oluwatayo et al., 2019). The way farmers get land can change their investment intent, daily farm management routines, and overall output. When land tenure is stable, farmers are more comfortable putting money into soil fertility, water control systems, and other upgrades, but if arrangements are uncertain or temporary, they might hold back, because long term thinking and proper use of resources becomes difficult (Hassan et al., 2025).

The outcomes in Table 5 suggest that 45.7% of the respondents obtained land through hiring, 29.5% inherited it, and 24.8% bought it directly. Put differently, many onion growers seem to depend on rented plots, while smaller shares have rights through purchase or inheritance. The common use of hired and leased farmland implies that insecurity of tenure is widespread in this locality, and that condition can restrict farm expansion, reduce willingness to invest, and slow down adoption of efficiency boosting practices. Also, land that becomes divided through inheritance, or pieces obtained by rental, can reduce economies of scale, and make day to day operations less smooth (Oluwatayo et al., 2019).

Method of Land Cultivation

Field management and land cultivation practices are key determinants of crop establishment, farm efficiency, and overall productivity (Hwang et al., 2025). The way farmers prepare the land really shapes soil condition, planting timing, labour use, and then, later on, the final crop yield. When cultivation is done with mechanization it tends to push operational efficiency, mainly because labour intensity drops, soil aeration improves, and planting beds become more even. From the results in Table 5, most respondents, about 83.5%, worked their farmland manually using simple farm tools, while only 16.5% used mechanized methods for land preparation. This kind of dominance of manual cultivation suggests a low level of mechanization among the onion growers in the study area. Using crude tools can actually increase drudgery and reduce the timeliness as well as the quality of land preparation. It can also cap the scale of production, especially during those peaks farming periods when labour demand is high. Also, manual tillage can create poor soil tilth, and that may disturb crop establishment, plant growth, and the yield itself (Hasan et al., 2024). A few things seem to explain why mechanized cultivation stays low. These include lack of access to tractors and other farm machinery, high costs when machinery is hired, inadequate credit facilities, small land parcels plus fragmentation, and weak rural infrastructure (Emmanuel et al., 2024). Because of these, farmers often don't invest in mechanized equipment or even consider renting it, even if it could boost efficiency and productivity. This observation matches Danji et al. (2025) who said 78.3% of onion farmers in Wukari Local Government Area of Taraba State relied on manual cultivation.

On the production efficiency side, manual land preparation can reduce labour productivity, lower operational efficiency, and may keep farmers from reaching the best possible yield levels. If these issues are handled—like through cooperative machinery arrangements, better rural infrastructure, and wider access to affordable farm equipment onion productivity and efficiency in the study area could improve quite a lot.

Method of Planting

Planting methods are kind of crucial for crop management, because they affect seedling survival, plant development, how well resources are used, and in the end, crop yield too. For onion production, the way farmers establish the crop can basically decide how many seedlings live, how even the spacing is across the field, and whether labour, water and fertilizers get used properly, which all together push production efficiency. From Table 5, the study showed that all the sampled farmers in the area used transplanting as their main, or preferred method, to establish onions. That suggests transplanting is almost like the standard method among irrigated onion farmers in that region. The fact that so many people choose transplanting maybe comes from several agronomic benefits. When seedlings are raised in nurseries first, then moved later to the main field, farmers tend to get better survival, more uniform plant arrangement, and a more careful use of resources like water and fertilizers (Sarker et al., 2017). In addition, transplanting helps with plant supervision in practice, it can lower the crowding effect, and it prevents the "over-crowding" problem, so seedlings can develop sturdier, leading to higher yields and more consistent results compared to direct seeding (Aboukhadrah et al., 2017).

Diagnostic Statistics

The diagnostic test presented in Table 6 provides important evidence on the adequacy of the stochastic frontier production model and inefficiency and production risk among onion farmers. The estimated sigma-squared (σ^2) value of 0.0027 is significantly different from zero, confirming that the composed error term is relevant and that a stochastic frontier approach is more suitable than an Ordinary Least Squares (OLS) regression for examining production behaviour (Kumbhakar et al., 2015; Greene, 2020). A non-zero sigma-squared indicates that output variation is influenced by both random shocks (v) and inefficiency effects (u), thereby validating the model specification (Aigner et al., 1977).

The estimated lambda ($\lambda = \sigma_u/\sigma_v$) value of 2.23298 is positive and greater than one, implying that the deviations of observed output from the frontier are primarily caused by technical inefficiency rather than uncontrollable stochastic events (Coelli et al.,2005; Bravo-Ureta et al., 2020). This shows that onion farmers are not fully utilizing available technologies or managerial practices to achieve maximum possible output. Practical attributes of inefficiency may include inappropriate input combinations, delayed agronomic practices, or limited access to improved production technologies.

Since λ compares inefficiency variance to random error variance, its significance also confirms the presence of production risk in onion farming. The random error term (σ_v) captures factors beyond farmers' control, such as weather variability, pest outbreaks, and price fluctuations that introduce uncertainty into production outcomes (Kumbhakar & Lovell, 2000; Greene, 2020). Thus, while inefficiency accounts for most of the deviation, production risk remains and influences farmers' performance.

The Gamma [($\gamma = \lambda^2/(1+\lambda^2)$)] is a parameter that express the degree level of inefficiency in the variance parameter, and is estimated to be 0.83. This, in practical terms, indicates that 83% of the total variation in onion output in the study area is due to technical inefficiency among farmers, while only 17% is due to random shocks or noise (Bravo-Ureta *et al.,* 2020). A gamma value close to one suggests that significant productivity gains are possible through improvements in managerial efficiency, the adoption of better input-use practices, and the strengthening of farmers' access to extension and production resources. The diagnostic test confirms that the stochastic frontier model is appropriate for analyzing onion production efficiency. The results reveal the presence of both production risk and technical inefficiency, with inefficiency being the dominant factor influencing output variation. Consequently, productivity improvements in onion farming can be achieved more through efficiency enhancement than simply increasing input quantities.

Table 6: Maximum Likelihood Estimates for Parameters of Cobb-Douglas Stochastic Frontier Production Model

Variable	Parameter	Coefficient	Std Error	P-Value
Constant	γ_0	1.320596	0.03245	0.000***
Seed	γ_1	0.423705	0.046711	0.000***
Fertilizer	γ_2	0.474985	0.043246	0.000***
Agro chemicals	γ_3	0.004139	0.005923	0.485
Labour	γ_4	0.096092	0.013279	0.000***
Variance Parameters				
Sigma-Square (u)		0.021078		
Sigma-Square (v)		0.0470668		
Lambda ($\lambda = \delta_u/\delta_v$)		2.232977		
Sigma^2($\delta^2 = \delta v^2 + \delta u^2$)		0.0026596		
$Gamma\ (\gamma = \lambda\hat{}2/(1+\lambda\hat{}2)$		0.83		

Source: Field Survey, 2025. Note: ***denote significance at 1% level.

Technical Efficiency Level of the Farmers

The stochastic frontier model was used to estimate the farm-level technical efficiency of onion farmers, and the results are presented in Table 7. The results of the analysis revealed that the average technical efficiency of the farmers was 0.658. This means that, on average, farmers were able to achieve only 65.8 percent of the maximum output possible with the resources they had. In practical terms, this suggests that there is a considerable opportunity, 34.2 percent to increase production without using additional inputs, simply by adopting better management practices and techniques used by the most efficient farmers.

Table 7: Distribution of Technical Efficiency Estimates

Efficiency scores	Frequency	Percentage (%)
1.00	0.00	0.00
> 0.90<1	3.00	1.18
>0.80≤0.89	51.00	20.08
>0.70≤0.79	92.00	36.22
>0.60≤0.69	50.00	19.69
>0.50≤0.59	14.00	5.51
>0.40≤0.49	2.00	0.79
>0.30≤0.39	14.00	5.51
>0.20≤0.29	14.00	5.51
>0.10≤0.19	14.00	5.51
Total	254	100
Mean	0.658	
Minimum	0.10	
Maximum	0..94	
Std. Dev.	0.200	

Source: Field survey, 2025.

The efficiency scores also show a wide variation among farmers. The most efficient farmer achieved a score of 0.939, indicating near-optimal use of resources, while the least efficient farmer scored only 0.102, reflecting significant underutilization of inputs. This variation reflects differences in farmers' skills, experience, and access to knowledge and resources, which directly influence how effectively they convert inputs into outputs. Further analysis revealed that about 76 per cent of farmers operated at efficiency levels between 60 and 89 per cent. This suggests that most farmers are relatively close to the production frontier, but there is still room for meaningful improvement. These improvements do not necessarily require more inputs; rather, they can be achieved through better planning, timely operations, and adoption of improved farming practices. The finding is consistent with previous study on onion production in sub-Saharan Africa. For example, Akamin et al. (2017) reported an average technical efficiency of 67%, indicating significant potential for productivity gains without increasing inputs.

Factors Affecting the Technical Efficiency Levels of Onion Farmers

The inefficiency model was specified to assess the factors that influence technical inefficiency in onion production. The variables included in the model were age, household size, education level, membership in farmer organizations, farming experience, extension contact, credit access, land cultivation technique, and planting technique. Out of these nine variables, five exhibited the *a priori* expected signs, while six were statistically significant at the 1%, 5%, and 10% probability levels. In interpreting the model, a negative coefficient indicates that the variable reduces inefficiency (i.e increases efficiency), whereas a positive coefficient implies that the variable contributes to higher inefficiency.

The results in Table 8 indicate that age significantly reduces technical inefficiency at the 1% probability level. This suggests that older farmers are less inefficient, which may reflect the dominance of young, energetic farmers in the study area. Younger farmers tend to be more willing to adopt innovations and take calculated risks, which can improve efficiency. On the other hand, older farmers may rely more on traditional practices, showing a tendency to resist change, which can increase inefficiency. These findings agree with Dessale (2017) who reported that age, education, improved seeds, training, and credit facilities significantly reduced technical inefficiency in vegetable production.

Table 8: Maximum likelihood Estimate for the parameters of Inefficiency Effect using Double-log stochastic Model

Variable	Parameter	Coefficient	Std Error	P-Value
Constant	γ_0	-7.35927	1.070208	0.000***
Age	γ_1	-0.06715	0.025292	0.008***
Household size	γ_2	-0.13923	0.070494	0.048**
Education level	γ_3	-0.09308	0.090607	0.304
Membership	γ_4	0.489469	0.25615	0.056*
Farming Experience	γ_5	-0.06438	0.031367	0.040**
Extension Contact	γ_6	0.082856	0.033599	0.014**
Credit Access	γ_7	0.014255	0.027958	0.610
Land Cultivation Tec	γ_8	0.905783	0.307042	0.003***
Planting technique	γ_9	-0.12041	0.126911	0.343

Source: Field Survey, 2025. Note*, **and *** denote significance at 10%, 5% and 1% respectively.

The coefficient for education was negative but statistically insignificant, suggesting that formal education does not have a strong direct effect on technical efficiency among onion farmers in the study area. Nevertheless, the negative sign indicates that education contributes marginally to efficiency improvement. Educated farmers are more likely to access and interpret agricultural information, maintain better records, and adopt improved technologies. This finding is consistent with Yahaya et al. (2019) who observed that higher levels of education were associated with increased efficiency among vegetable farmers.

Farming experience was found to have a significant negative effect on technical inefficiency, confirming the adage that "experience is the best teacher." Farmers with more years of onion production are better able to manage risks, anticipate seasonal variations, and respond to pests, diseases, and other agronomic challenges. The result shows that experienced farmers are likely to employ practices that enhance efficiency, regardless of their formal education level. This observation aligns with Yahaya et al. (2019), who reported that experienced farmers are generally more efficient.

Extension contacts, surprisingly, were positively related to inefficiency and statistically significant at the 5% level. This indicates that interaction with extension agents does not automatically translate into higher efficiency. Possible reasons include inadequate training of extension officers, insufficient quality of information provided, or infrequent visits that fail to induce meaningful changes in farm practices. While extension services are designed to promote improved cultural practices, the findings suggest that, in the study area, these services may not be effectively reaching farmers or influencing their decision-making. Robert et al. (2021) observed a positive influence of extension contact on vegetable output among Kiri Dam users in Adamawa State, whereas Alemu et al. (2002) reported opposite results, emphasizing that the impact of extension is context-specific.

The coefficient for credit access was positive but statistically insignificant, implying that access to credit does not have a considerable impact on technical efficiency in onion production. This may be due to delays in loan disbursement, small loan sizes, or diversion of funds to non-farming activities. Adams et al. (2020) reported similar trends, noting that structural constraints within rural financial institutions can weaken the effect of credit on efficiency. Land cultivation technique emerged as a highly significant factor, with a positive coefficient indicating that the current methods increase inefficiency. Most farmers in the study area rely on traditional techniques, such as manual hoeing, unlevelled fields, and primitive irrigation systems, which limit productivity.

Finally, planting technique was found to significantly influence efficiency. Farmers who employed the transplanting method were more efficient than those using broadcasting. Transplanting allows seedlings to be carefully spaced, ensures the survival of healthy plants, and reduces competition for nutrients, whereas broadcasting often leads to uneven plant density and lower yields. Zegeye et al. (2024) similarly reported that transplanting with proper spacing improves bulb size, quality, and onion yield. This emphasizes the importance of adopting appropriate planting techniques to optimize resource use and maximize output.

CONCLUSION

The research found that onion farming in Taraba State could be a profitable small-scale business with a lot of room for expansion. It was also found that farmers have not reached their maximum production levels, on average only achieving a technical efficiency of 65.8%. Use of fertilizer, seeds, and other chemicals not only help to increase the output but also help in lowering the risks of production. On the other hand, labour is leading to inefficiency and fluctuation in the yields.

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