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Profit Efficiency of Sorghum (*Sorghum bicolour* (L.) Moench) Production among Smallholder Farmers in Southern Agricultural Zone of Nasarawa State, Nigeria

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Abstract

The research examines the profit efficiency of sorghum production among smallholder farmers in the Southern Agricultural Zone of Nasarawa State, Nigeria. Utilizing a multi-stage sampling method, 200 sorghum growers were selected as sample size for the study. Data were analyzed using Descriptive Statistics, Gross Margin and Stochastic Profit Frontier Function. Results show average sorghum farmers in the research area had 1.0 ha of farmland under cultivation; production of sorghum was profitable at ₦85,006.63/ha/annum; the return on investment for sorghum production was ₦1.54k; the average Profit efficiency was 0.55; while potential profit in the study area was ₦123,259.24/ha/annum. The findings reveal that the profit lost due to inefficiency was statistically significant at ₦38,252.87/ha/annum the coefficients of seed price, 0.329(P<0.05) and farm size, 0.807(P<0.05) were major factors influencing the quantum of profit efficiency, while the determinants of profit inefficiency were household size (with coefficient 1.040, P<0.05) and access to credit (with coefficient -1.428 P<0.05). Constraints to sorghum production were inadequate credit facility, insecurity, insufficient improved seed, and inadequate extension visits. Therefore, for greater profit margins and improved production efficiency, sorghum growers should endeavour to adopt improved seeds and have easy access to credit facilities. Farmers' extension contact should be increased and extension services should be packaged to include training on optimal utilization of production inputs and prices. The security architecture in the area should be enhanced to guarantee unhindered and safe access to farmlands.

Keywords: Smallholding sorghum farmers, profit, efficiency

Introduction

Sorghum ranks as the fourth-largest among the family of cereals behind maize, wheat and rice. Scientifically known as *Sorghum bicolour* (L.) Moench. Sorghum products remain a diet for more than five hundred million people globally (Smith and Fredricksen, 2000). Gosa and Jema (2016) reported that sorghum is cultivated by smallholder farmers with limited resources and that it is largely grown in arid to semiarid environments. It has resilience traits and is adaptable to agro-climatic adverse conditions to which other staple crops like maize and rice could be susceptible. According to FAO (2019), sorghum is an important cereal crop, contributing 50% of all cereal production and occupying about 45% of all cereal-growing land in Nigeria. Sorghum crop is used holistically from the grain to the residues. The stem and leaves are used for the construction of fences, thatching by rural farmers and feeding livestock. The grain has wide applications both for human and livestock consumption and as raw material for beverages (Aduba *et al*., 2013). Profit efficiency is the ability of the farm to maximize its profits given its predetermined cost structure, pricing, and factor levels, while profit inefficiency refers to the farm's inability to maximize its profit given its predetermined cost structure, pricing and factor levels (Ali and Flinn, 1989).

Figure 1 shows the trend of sorghum yield/ha in Nigeria (2000 to 2021). A steady increase in the sorghum yield per hectare from 1120 kg/ha in 2000 to 1350 kg/ha in 2006 was observed. This represented a 20% increase in yield per hectare within the period. However, the subsequent years (2007 to 2021) witnessed regular fluctuation in sorghum yield/ha in the country. The highest yield was observed in 2010 at 1439 kg/ha (slightly above the global average of 1435 kg/ha) but later declined by 18% to 1179 kg/ha in 2021. The yield fluctuation could be attributed to, among other factors, inefficiency in production management that characterized smallholding farming in Nigeria. Similarly, the national output of sorghum production in Nigeria was at its peak in 2006 with 7 million tonnes (Figure 2). Since 2007, national output trended downward at 4.29% to 6.7 million tonnes in 2021 from 7 million tonnes in 2006.

Efficiency means the absence of waste or using resources as effectively as possible to satisfy the farmers' needs and goals. It is the process of coordinating human, material, and financial resources to accomplish a specific goal (Kumbhakar *et al*., 2015). Profit efficiency is the ability of the farm to maximize its profits given its predetermined cost structure, pricing, and factor levels. Profit inefficiency is the loss of profits due to non-frontier operations (Ali and Flinn, 1989). Several institutional and socioeconomic factors affect a farm's profit efficiency (Zalkuwi *et al*., 2014b). According to FAO (2019), Sorghum is a significant cereal crop contributing 50% of all cereal production and occupying about 45% of all cereal-growing land in Nigeria. An average of 1179 kg/ha was reported to be produced, this shows that the productivity of the crop is still low in Nigeria (FAO, 2022).

Uncovering the profit-inhibiting factors in the area is imperative for policymakers to focus interventions in the enterprise, particularly with the dearth of relevant information concerning profitability. Maximizing profit in farm enterprise is an important incentive for sustenance and up scaling production to guarantee employment and poverty alleviation. Hence to bridge the knowledge gap, this study is aimed specifically at meeting the following research objectives: estimate the profitability of sorghum production; determine the profit efficiency of sorghum farmers; estimate the relationship between inputs prices and profit level of sorghum farms; examine determinants of profit inefficiency among sorghum growers; and, identify sorghum production challenges.

Methodology

Study Area

The research was conducted in the Southern Agricultural Zone of Nasarawa State, with Obi town as headquarters. The zone is made up of five Local Government Areas namely; Lafia, Doma, Obi, Awe, and Keana. The area has a distinct wet and dry season and a tropical sub-humid climate. Nasarawa State is situated in the country's center belt region. It is located between longitude 7^0 and $9^037'$East of the Greenwich Meridian and latitude $7^045'$ and $9^025'$ north of the equator. The average annual rainfall is between 1200 to 2000mm and annual temperature ranges from 25^0C to 28^0C. A total of 27,272km2 of land make up the state. Nasarawa State's economy is based mostly on agriculture which produces a wide range of cash and food crops including yam, sorghum, maize, cassava, rice, cowpea, melon, sesame, oil palm, mangoes, cashew, etc. are grown in the region (NASG, 2017).

Sampling Techniques

The smallholder sorghum farmers in Nasarawa State's Southern Agricultural Zone were the study's target group. Respondents were chosen using a multiple-sampling technique. Three (3) LGAs in the Zone were purposively selected due to their high prevalence of sorghum cultivation. The selected Local Government Areas were Awe, Lafia, and Obi. In the second stage, four (4) villages from each Local Government Area that are well-known for their sorghum productions were purposively sampled (See Table 1). Ten per cent (10%) of the sampling frame of smallholder sorghum farmers in each village was randomly selected. The study used 200 smallholder sorghum farmers in total.

Model Specification for the Stochastic Profit Frontier

Profit efficiency is the proportion between real profit and the projected profit. Standard profit functions assume that dealers of input and sorghum producers are price takers. This premise guides the current investigation. This suggests that the sorghum farmer maximizes profit by choosing the best amount of factor combination given the factor and product prices. According to Umar *et al*. (2017), The *i-th* farm's normalized real stochastic frontier profit function is expressed as follows:

$\pi i = \pi / P = f(Pi, Xi)\exp(vi - u_i)$……..(1)

Where πi is the normalized real profit of the *i-th* farm;
Pi is the vector of the normalized factor price of the *i-th* farm;
Xi is the vector of the fixed factor of the *i-th* farm;

P is the product price, which serves as a factor for normalization;
(Vi– Ui) is the composite error term:
Vi are random variables assumed to be identical independently distributed (iid) ~ N (0, σ^2v), which capture the effects of statistical noise;
Ui is non-negative random variable accounting for profit inefficiency and are assumed to be iid ~ N (0, σ^2u) with truncation at zero distribution.

$$u_i = \delta_0 + \sum_{i=1}^{k} \delta_i S_i + \varepsilon_i \, i = 1, 2, 3, - - - n \ldots (2)$$

Where δ0and δi are unknown parameters;
Si is the vector of explanatory variables of the profit inefficiency.
According to Yahya *et al*. (2016), Umar *et al*. (2017), Sadiq and Singh (2015) and Muhammad *et al*. (2018), the profit efficiency of the *i-th* farm in stochastic frontier functional form is determined as a ratio of the real (π_i) to the projected profit (π_i*) given the price of variable factors and the amount of fixed-factor used by the *i-th* farm. It is written mathematically as follows:

$$\text{Profit efficiency } (\pi_{Ei}) = \frac{\pi}{\pi_i^*} = \frac{F\left(P_{i,}X_i\right)\exp\left(V_i - U_i\right)}{F\left(P_{i,}X_i\right)\exp(Vi)} \ldots . (3)$$

$(\pi_{Ei}) = \exp(-U_i)$
By substitution,

$$= \exp\left(-\delta_0 + \sum_{i=1}^{k} \delta_i Z_i + \varepsilon_i\right) \ldots \ldots (4)$$

Where π_{Ei} takes the value between 0 and 1.
Equations 1 and 3 can be explicitly specified in Cobb-Douglas Model as follows:

$$In\pi_i = \beta_0 + \beta_1 lnP_{labour} + \beta_2 lnP_{agroch} + \beta_3 lnP_{fert} + \beta_4 lnP_{seed} + \beta_5 lnf_{size} + e \ldots\ldots (5)$$

Where, π_i= normalized profit (₦) for ith farmer, P_{labour}= normalized price of labour (₦/manday), P_{agroch} = normalized price of agrochemical (₦/litre), P_{fert} = normalized price of fertilizer (₦/Kg), P_{seed} = price of seed (₦/Kg), f_{size} = area of land cultivated (ha), $\beta_0 - \beta_5$ = estimable parameters.

The explicit form of equation 2, which account for respondents' socioeconomic features as a determinant of profit inefficiency is specified as follows:

$$U_i=\delta_0+ \delta_1 S_1 + \delta_2 S_2 + \delta_3 S_3 + \delta_4 S_4+\delta_5 S_5+\delta_6 S_6+\delta_7 S_7 \ldots.. (6)$$

Where, U_i= profit inefficiency of the i-th farmer,

S_1= Age of the *i-th* farmer (year),

S_2 =Size of Household of the *i-th* farmer (Number),

S_3=Level of educational attainment of the *i-th* farmer (Years)

S_4= Years of experience in the farming of the *i-th* farmer in sorghum production,

S_5= Access to credit (access =1, otherwise=0)

S_6 = Membership of cooperatives association (member=1, otherwise=0)

S_7= Extension visits (number of visit)

$\delta_0 – \delta_7$= parameters to be estimated.

The link between the variance of the random errors ($\sigma^2 v$), the variance of the profit inefficiency effect ($\sigma^2 u$), and the overall variance of the model (σ^2) can be expressed as $\sigma^2 = \sigma^2 v + \sigma^2 u$. This estimates the entire variation in profit from the projected that may be attributable to profit inefficiency (Battese and Corra, 1977). However, Battese and Coelli (1993) produced a log-likelihood function after substituting σ^2vand $\sigma^2 u$ with $\sigma^2 = \sigma^2 v + \sigma^2 u$, estimating gamma ($\gamma$) as $\gamma = \sigma^2 u/(\sigma^2 v+\sigma^2 u)$

The proportion of inefficiency in the total residual variance is indicated by the Gamma (γ), which has a value between 0 and 1. The presence of inefficiency is indicated by a score that is close to 1, whereas the absence of such evidence is shown by a score of 0. The stochastic profit frontier function and the inefficiency model were both estimated using FRONTIER 4.1. Software.

Gross Margin Specification

As a result of the small size of the sorghum farms in the area, profit estimation is done using the gross margin model (GM) while holding the fixed cost constant (Olukosi and Erhabor, 1988).

$$GM = \Sigma QyPy - \Sigma Xi Pxi$$

Where: GM = gross margin (₦/ha); Qy = Product of crop (Kg/ha); Py = unit price of the product (₦/Kg); QyPy = total revenue from the production (₦/ha); Xi = quantity of the i^{th} factor used in Kg per hectare (seed, hired labour, or agro-chemicals); Pxi = Price per Kg of the i^{th} factor (₦/Kg); XiPxi = total cost associated with the i^{th} factor per hectare (₦/ha); Σ = Summation sign

Results and Discussion

Profitability of Sorghum Production in the Study Area

Table 2 shows the estimated gross margin was ₦85,006.63 per hectare; while the total variable cost was ₦55,350.01 per hectare. Table ii shows that labour cost constituted 85.10% of the total variable expenses. This indicates that labour was the most significant cost of sorghum production. The return on investment was ₦1.54, indicating that growing sorghum is a lucrative enterprise with a profit of 54 kobo for every naira spent. This outcome is in agreement with the findings of Oladeji (2014), Mohammed (2016), Sani *et al*. (2013), Baiyegunyi *et al*. (2014), Zalkuwi *et al*. (2014), and Aduda *et al*. (2013).

Frequency distribution of profit efficiency

Frequency distribution of farm-specific profit efficiency score analyzed by stochastic frontier model for sorghum growers is shown in Figure 3 from 11% to 93%, sorghum growers had wide variability of profit efficiency. Profit efficiency for approximately 5.5% of respondents ranged from 0.11 to 0.20, 0.21 to 0.30 (8 %), 0.31 to 0.40 (17.5 %), 0.41 to 0.50 (15.5 %), 0.51 to 0.60 (9.5%), 0.61 to 0.70 (11%), 0.71 to 0.80 (16.5%), 0.81 to 0.90 (15%), and 0.91 to 1.00 (1.5%). Figure 3 shows that sorghum farmers attained an average profit efficiency of 55%. Thus, average sorghum growers could still increase their profit by 45 per cent and reach the frontier by increasing technical and allocative efficiency. The finding agreed with Mohammed (2016), who reported that sorghum farmers in Kaduna state had a mean profit efficiency value of 0.57. Figure 3 also shows that 60% of the sorghum farmers were operating at less than 65% profit efficiency level; while 83% of the farmers attained less than 80% profit efficiency level. The result portends a huge loss of potential profit by 45% on average. This calls for deliberate efforts by the relevant stakeholders including extension workers to address the loss.

Average Profit statistics

Table 3 shows the real or observed profit per hectare of sorghum production was ₦85,006.63, while the potential or the frontier profit per hectare of sorghum was ₦123,259. Table iii also shows that the profit lost per hectare of sorghum farm as a result of inefficiency was ₦38, 252.87. This constituted 45% of the average profit earned. Profit efficiency's coefficient of variation (CV) was 29%. This suggests that farmers' profit efficiency levels have a high degree of convergence given the right extension guide. The result of the paired sample t-test, 28.433 ($P<0.05$) implies that there was a significant difference between the observed and potential profit of the sorghum farmers.

Profit Function and Sources of Profit Inefficiency

Table 4 shows gamma (γ), with an estimated value of 0.92 differs significantly from zero, which further confirmed the existence of major inefficiency. Gamma's value shows that farmers' inefficiency, rather than random variables, was responsible for a 92 % difference in farms' real profit from the projected profit.

Additionally, at a 1% probability value, the predicted sigma square (σ) of 0.569 was statistically significant. This implies a well-fit model and accuracy of assumption for the composite error term. The coefficient of the seed displayed a positive sign and was statistically significant at a 1% probability value. It implies that a one per cent increase in quality seed with a higher price would increase the profit efficiency margin by 0.33%. This finding is corroborated by Dang (2017) and Zalkuwi *et al*. (2014a). At a 1% significant level, the coefficient of farm size was also estimated to be statistically significant. This shows that with a unit per cent increase in the farm size, the profit efficiency margin would increase by 0.81%. This may be explained by the fact that larger farms experience greater economies of scale in terms of production costs, which results in higher profits compared to smaller farms. The findings of Muhammad *et al*. (2018), and Umar *et al*. (2017), are in agreement with this result. Table iv shows that, at 1% level of probability, the predicted coefficient on credit availability was statistically significant, with the expected sign. This suggests that enhancing access to credit facilities would cause sorghum production to become less inefficient (and therefore more profitable). Evidence shows that farmers with greater access to financing generate profit margins much more than those with limited access to credit. This result follows that of Zalkuwi (2013) and Zalkuwi *et al.* (2014b). The computed coefficient for household's size is statistically significant at 1% level of probability.

Constraints to Sorghum Production

Table 5 shows the severity of challenges confronting sorghum farmers in the area. With a mean score of 3.80, the inadequate credit facility was the study area's biggest barrier to the production of sorghum. This could be the most likely cause of the preponderance of smallholder farmers in the area. Aduda *et al.* (2013) observed that one of the significant challenges to sorghum production is the lack of sufficient finance facilities. With a mean score of 3.75, the research area's insecurity was also shown to be a substantial impediment to sorghum production. According to a recent study by Solomon (2021), food insecurity brought about by farmer-herder disputes had an impact on crop production and grazing activities, which led to low agricultural productivity, unstable food supplies, insufficient food availability, and low food consumption. Inadequately improved seeds received a mean score of 3.36, which the respondents rated as another major challenge. This corroborates Emmanuel *et al*. (2017) result that insufficiently improved seed was a significant barrier to sorghum production in semi-arid Tanzania. Poor extension worker visits to the farmers, which had a mean score of 3.30, also constituted a challenge to sorghum production. This was evidenced by a 45 % profit loss due to the inefficiency of the farmers. The outcomes are consistent with those of Aduda *et al*. (2013). High input cost with a mean score of 3.14, is another constraint to sorghum production. Sani *et al*. (2013) observed similar findings. Other significant challenges confronting sorghum production in the study were inadequate tractor service, poor market price of sorghum and poor state of the road network in the study area.

Conclusion

Sorghum Production was a profitable enterprise with a gross margin of ₦85,006.63 per hectare and a return on investment was ₦1.54. The potential profit in the study area was ₦123,259.24/ha, while profit lost due to inefficiency was statistically significant at ₦38,252.87/ha; the coefficients of seed price, 0.329($P<0.05$) and farm size, 0.807($P<0.05$) were major factors influencing the quantum of profit efficiency, while the determinants of profit inefficiency were household size (with coefficient 1.040, $P<0.05$) and access to credit (with coefficient -1.428 $P<0.05$). Constraints to sorghum production were inadequate credit facility, insecurity, insufficient improved seed, and inadequate extension visits. The results therefore call for policies to boost extension services to the farmers. Such extension service should be targeted at production management efficiency training. Access to credit facilities should be made easier. Farmers should form cooperatives so that they can have easy access to agricultural credit provided by Agricultural Banks, Micro-Finance Banks and the Anchored Borrowers' Programme of the Central Bank. Security architecture should be enhanced through community-based policing to guarantee secured farming in the area.

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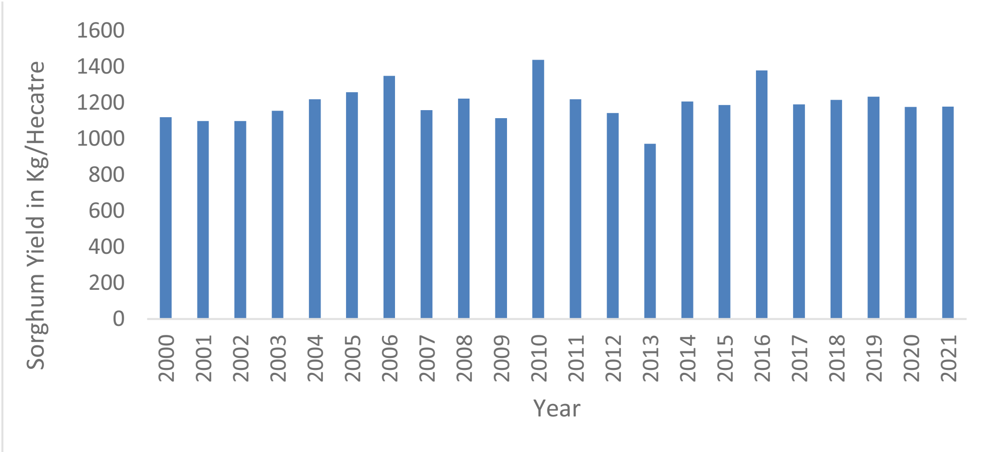

Figure 1: Sorghum Yield /ha in Nigeria; Source: FAOSTAT (2022)

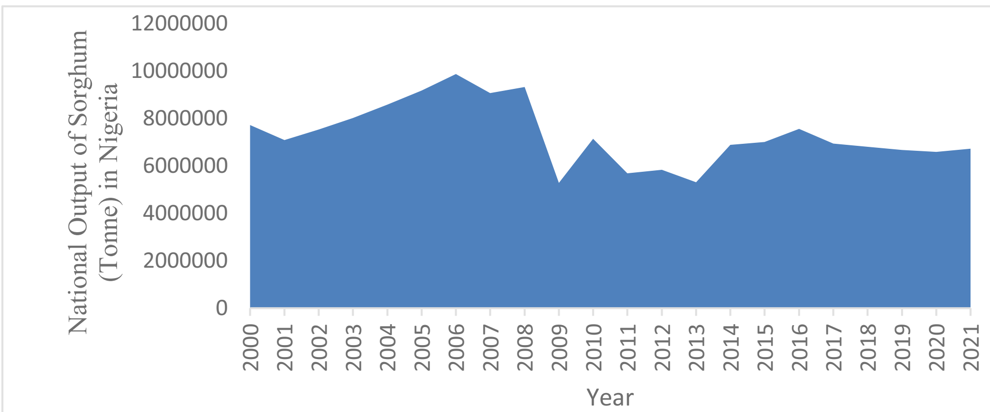

Figure 2: Sorghum National Output in Nigeria (2000 to 2021)
Source: FAOSTAT (2022)

Table 1: List of registered sorghum farmers in the areas

LGAs	Villages	Sample frame	Sample size 10%
Awe	Ibi	245	25
	Asembere	89	9
	Doruwan- wuse	174	17
	Tsohon- wuse	145	15
Lafia	Gwayaka	204	20
	Kiguna	124	12
	Oleye	215	22
	Oriso	130	13
Obi	Obi	270	27
	Owolosoho	158	16
	Madaki	135	14
	Amawa	97	10
Total	12	1986	200

Source: NADP and reconnaissance survey data (2021)
Note*: Wuse is suffix name to Doruwan wuse and Tsohon wuse village respectively*

Table 2: Gross Margin of Sorghum Production

Variables	Unit	Average Quantity	Unit Price	Cost/ha(₦)	%
1. Variable Cost					
i. Labour	Man-days	41.22	1,142.68	47,101.35	85.10
ii. Agro-chemicals	Litres	1.47	963.1	1,415.71	2.56
iii. Fertilizers	Kg	78.81	58.22	4,588.60	8.30
iv. Seed	Kg	1.70	181.04	307.77	0.56
v. Transportation	₦			1,936.67	3.50
2. Total Variable Cost(TVC) = i+ii+iii+iv+v	₦/ha			55,350.01	
3. a) Output	Kg	732.13	191.71		
b) Revenue	₦/ha			140,356.64	
4. Gross Margin(TR−TVC)	₦/ha			85,006.63	
5. Returns per naira invested(GM/TV)				1.54	

Source: Field survey (2021)

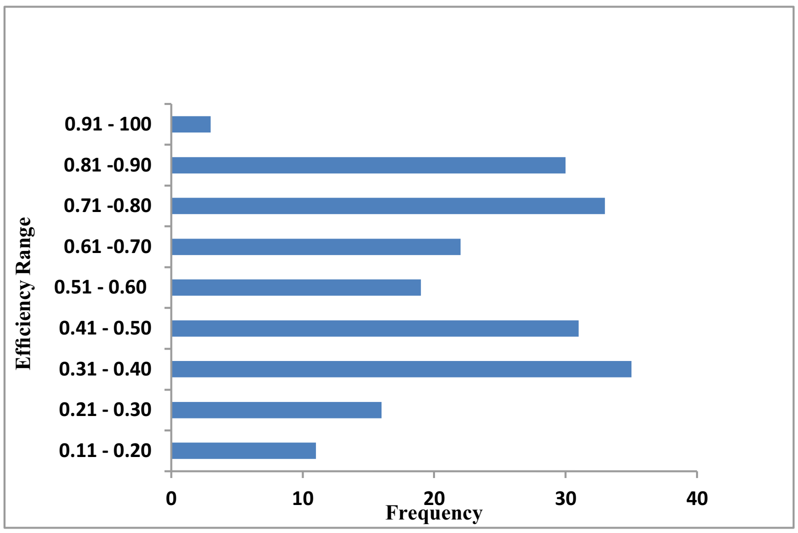

Figure 3: Frequency distribution of profit efficiency

Table 3: Descriptive statistics of the observed and potential profit per hectare

Items	Lowest	Highest	Average	STD	CV (%)
Profit Efficiency	0.11	0.93	0.55	0.16	29
ObservedProfit/Ha	₦2,130	₦290,249	₦85,006.37	2549.12	3
Profitloss/Ha	₦1,895.7	₦20,317.43	₦38,252.87	2098.37	5
PotentialProfit^x/Ha	₦4,025.7	₦310,566.43	₦123,259.24	450.75	0.4

Source: Estimated data obtained by a field survey (2021)

x= real profit + (1-profit efficiency in naira); CV= Coefficient of variation; STD = standard deviation

Table 4: Estimated profit function and sources of profit inefficiency

Variable	Parameter	Coefficient	Standard Error	t-ratio
Constant	β_0	11.018	1.120	9.84***
Mean Price of Labour	β_1	− 0.085	0.064	−1.33
Mean Price of Agrochemical	β_2	0.005	0.009	0.59
Mean Price of Fertilizer	β_3	− 0.008	0.009	−0.92
Mean Price of Seed	β_4	0.329	0.115	2.86***
Farm Size	β_5	0.807	0.139	5.81***
Intercept	δ_0	− 1.267	1.830	0.69
Age	δ_1	− 0.042	0.466	−0.09
Household Size	δ_2	1.040	0.303	3.43***
Education	δ_3	0.137	0.283	0.48
Farming experience	δ_4	− 0.327	0.203	−1.61
Access to credit	δ_5	− 1.428	0.447	−3.20***
Membership of cooperative association	δ_6	0.627	0.331	1.89*
Extension visit	δ_7	0.356	0.292	1.22
Sigma-squared		0.569	0.148	3.84***
Gamma		0.918	0.049	18.55***

Note:* **&*=statistical significance level of 1%&10% respectively

Table 5: Constraints militating against Sorghum Production

Constraints	Mean Score
Inadequate credit facilities	3.80***
In security on the farm	3.75***
Inadequate improved seeds	3.36***
Inadequate extension visits	3.30***
High cost of inputs	3.14***
Non- availability of tractors	3.08***
Poor price of the sorghum	3.04***
The Poor state of roads	2.95***
Poor sorghum production management	2.72
Insufficient labour	2.67
Soil fertility problem	2.63
High cost of transportation	2.59
Flood	2.48
Others (inconsistency in government policies/theft)	2.46
Distance to the market	2.44
Drought	2.28
Pest and diseases	2.08

Source: Field Survey (2021) *Note: Weighted Mean (WM) =2.87; Decision rule: Constraint with a mean score ≥ to the weighted mean is significant. ***=Significant*