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Endogenous Effect of Agricultural Land-Use Intensification on Production Efficiency among Food Crop Farmers in Oyo State, Nigeria

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ABSTRACT

Background and Objective: Agricultural land-use intensification reduces unusual cutting down of forest resources and leads to an economic pathway of improving farmland productivity if sustainably practised. Therefore, this study looked into the endogenous effect of agricultural land-use intensification on production efficiency among food crop farmers in Oyo State, Nigeria. **Materials and Methods:** The study used a two-stage sampling method to select 346 respondents. Primary data were collected with the aid of a questionnaire and estimated using descriptive statistics, Ruthenberg (R) index, stochastic frontier analysis and two-stage least square regression. **Results:** Most farmers are involved in the cultivation of three food crops (maize/cassava/okra) at least with an average farm size of 7.67 ha. The R-index for measuring agricultural land-use intensification revealed that 3.18, 19.65 and 77.17% of the farmers fell into low ($R<33\%$), medium ($33\leq R\leq 66\%$) and high ($R>66\%$) land-use intensities, respectively. The mean production efficiencies were 0.5492, 0.7788 and 0.7872 for cassava, maize and okra respectively. Also, land-use intensification positively influenced maize ($p = 0.030$) and cassava ($p = 0.039$) farms' efficiency levels. **Conclusion:** It is concluded that farm production efficiency is considerably dragged by agricultural land-use intensification hence the findings of this study may be relevant for making agricultural land policy.

KEYWORDS

Agricultural, land-use intensification, production efficiency, endogenous effect, food crop farmers, Ruthenberg (R) index, stochastic frontier, Two-Stage Least Square (2SLS) regression

INTRODUCTION

Agriculture is an integral source of food production and it plays a vital role in both local as well as global economic development[1-3]. For instance, it is evidenced from many of the studies[4-7], that the majority of the dwellers in rural areas derive their livelihoods from agricultural activities in Nigeria. Besides, it is intrinsically aware that the farmers have ever since the existence of mankind been the soul of nations, particularly in terms of food supply to the masses. However, the Nigerian economy including the agricultural sector suffers a lot despite the available natural and human resources. In terms of agricultural practices, the majority of farmers who cultivate food crops are inefficient smallholders because they lack access or security over farmland, farm technological advantage as well and infrastructure. These set of farmers depend on climatic conditions to plan their activities.

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Moreover, farming households particularly the smallholders endure low income from agricultural production and continue to struggle with food insecurity, poverty as well as climatic risks[8]. Labour and capital inputs such as fertilizers, irrigation and other crucial soil amendments needed for sustainable agricultural land-use intensification are not always affordable to the farmers. Yet, they represent some of the major indicators of agricultural intensification practice that is beneficial in terms of forestland conservation and enhanced food production. This challenge is likely to count down on the performance of agricultural land-use intensification strategy and consequently the achievement of the Sustainable Development Goal (SDG 2) 2030 agenda in meeting adequate food supply and eradicating hunger/malnutrition[9]. Land-use intensity refers to any practice (system of land-use) that increases productivity per unit area of land. Partly, the reasons for land-use intensification are the increased trends in human population growth and the shortage of farmland parcels.

Agricultural intensification, as viewed by many researchers is typically known as a means of preventing deforestation while planning to increase farm output per hectare in an agrarian system. In other words, land-use intensification is a process of continuous or permanent cultivation/farming on a fixed land area with an increased rate of utilization of other farm inputs such as labour, fertilizers, manure, as well as improved seeds in order to obtain optimum farm produce[8-11]. Past studies have reported that agricultural intensification depends on efficient land use and proper reallocation of farm resources[12-14]. In addition, it is noticeable that some of the efforts made by farmers and governments to increase farm production efficiency have not effectively achieved the major goal of self-sufficiency in food production in Nigeria. This is likely to be caused by neglect of livelihood strategies and poor land use management practices by farmers in food crop production.

The importance of farm efficiency and productivity in agricultural development cannot be overemphasized and so measurement of efficiency is at the centre point of discourse for every decision-making unit targeting the optimization of both production resources/inputs and outputs. In agriculture, the analysis of efficiency is concerned with the possibility of farms producing at the optimum level using a least-cost resources combination or minimum inputs level. Efficiency in farm production is a topical issue, it is normally planned toward by individual farming households in the agricultural development process as in some African countries[15]. Generally, production efficiency is the attainment of production goals without any resource wastage.

Studies on resource use-efficiency among farming households in rural areas are uncountable. Also, there are other research works that have identified some economic variables which have an influence on the efficiency of farm production. For example, previous works by, Folayimi[16], Obianefo *et al.*[17], Folayimi *et al.*[18] had delved into the adoption effects of improved technologies on the efficiency of crop farming, the influence of climate-smart adaptation measures on farm productivity and the efficiency, effects of agrochemical use and technological gap on the efficiency of rice farm production as well as assessment of non-farm income on poverty and farm production efficiency of rural households in Nigeria. But, there is a need for continuous work in agricultural research in order to fill the gaps in knowledge. Therefore, this study viewed that the nexus between agricultural land-use intensification practice and efficiency of food crops production among farmers in Nigeria is necessary for consideration. For this reason, this study investigated the following research questions:

- What is the level of agricultural land-use intensification among food crop farmers in Oyo State, Nigeria?
- What are the food crops cultivated by individual farmers and the level of the production efficiency among food crop farmers in the study area?
- What is the effect of land-use intensification practice on the production efficiency level of food crop farmers?
- What are the constraints impeding the efficiency of farm production among food crop farmers in Oyo State, Nigeria?

MATERIALS AND METHODS

Study area: The study was carried out in Oyo State located in South-West Nigeria from October 2018 to December, 2021. Oyo State is made up of thirty-three Local Government Areas (LGAs) which were officially divided into four Agricultural Zones of Oyo State Agricultural Development Programme (OYSADEP). The zones are Ibadan/Ibarapa, Oyo, Saki/Iseyin and Ogbomoso. Ibadan/Ibarapa has fourteen LGAs/Blocks, Oyo and Ogbomoso have five LGAs/Blocks each and Saki/Iseyin also has nine LGAs/Blocks in their zones, respectively for administrative conveniences. Oyo State is very large in terms of land area (28,454 km^2) and population 6.6 million. Its atmospheric condition both in the wet and dry seasons is favourable for human habitat. The state is known as the food basket of Nigeria, because of its vegetation/soil types which are rich in minerals. Several economic activities such as farming, trading, arts and crafts, teaching, civil services and apprentices are major occupations of people.

Population, sampling technique and data collection: The population for this study comprised all food crop farmers in Oyo State, Nigeria. A two-stage sampling technique was employed to sample the population frame (N) in which the sample size (n) was drawn. The first stage involved a random selection of two zones (Ibadan/Ibarapa and Ogbomoso Zones) which is equivalent to half (50%) of the state. In the second stage, simple random sampling was used to select one-third of the LGAs out of all LGAs made up of these zones. Thereafter, with the known population of the food crop farmers in all Local Government Areas selected for the study, the appropriate sample size was determined using the population proportionate factor stated as[19]:

$$S = \frac{X^2 \; NP\,(1-P)}{d^2 \; (N-1) + X^2 \; P\,(1-P)} \tag{1}$$

The study drawn population size (N) equal to 60348 and assumed a population proportion (P) of 0.50, Chi-square (χ^2) for 1 degree of freedom at 95% confidence level, normally ($1.96\times1.96 = 3.841$) and degree of accuracy (d) of 5%. This method of obtaining sample size is based on probability assumption which permits every individual farmer to be a good representative of the entire population in the study area. Therefore, the sample size is calculated as:

$$S = \frac{3.841\times 60348\times 0.5\,(1-0.5)}{(0.05)^2 \; (60348-1) + 3.841\times 0.5\,(1-0.5)} = 382 \text{ farmers} \tag{2}$$

Hence, a total of 382 copies of the questionnaire were administered to farmers during field exercises. However, the study confidently made use of 346 questionnaires for analysis at the end. The leftover questionnaires were not found useful due to inconsistent information and poor responses from the target farmers.

Statistical analytical tools: This research employed both descriptive and inferential statistics for data analysis. Descriptive analysis (frequency tables, percentage, mean, standard deviation), Rothenberg index, Stochastic Frontier Analysis (SFA) and Two-Stage Least Square regression (2SLS) analysis were estimated according to each of the specific objectives.

Rothenberg index: Rothenberg index was computed by dividing the number of years for which cropland is consecutively cultivated before being allowed to fallow (T_i) with the length of cropping cycle C_i, (addition of years of consecutive cultivation and period of fallow) (Rothenberg and MacArthur[20]). Thus, the land-use intensity, (Li) of ith farmer measured by the R-value, ($0<R\leq1$) is specified as land-use intensity:

$$Li = \frac{T_i}{C_i}\times 100 \tag{3}$$

Stochastic Frontier Analysis (SFA): Stochastic Frontier Analysis (SFA) was employed to estimate the level of production efficiency and its determinants among food crop farmers. This approach has been popularly used in production studies for the measurement of the efficiency of a specific production unit[21]. It is paramount to note that the specification of stochastic production frontier analysis in most cases followed the Cob-Douglas production function which is stated as:

$$LnY_i = \beta_0+\beta_i ln+(V_i-U_i) \tag{4}$$

Where:

Ln = Natural logarithm
Y_i = Quantities of food crops (maize, cassava and okra) in kilogram
X_i = Vector of input variables included in the model
β_i = Vector of unknown parameters to be estimated
V_i = Disturbance term with a symmetric distribution error term
U_i = Disturbance term with a half-normal distribution called non-negative error term

V_i is assumed to be independently and normally distributed with zero mean while, U_i has half-normal or exponential distribution[22].

The inefficiency model can be stated as follows:

$$U_i = \alpha_0+\alpha_i \ln Z_i+e_i \tag{5}$$

Where:

i = 1, 2...k
U_i = Inefficiency component of ith farmer
α_0 = Constant term
α_i = Vector of unknown parameters to be estimated
Z_i = Vector of independent variables included in the model

Hence, the estimation of the inefficiency model usually reveals the independent variables that determine the technical efficiency of farmers depending on the sign of coefficient estimates. Technical efficiency is the ratio between the output (Y_i) assuming technical efficiency and the technically efficient output (corresponding frontier output Y*). The efficiency scores normally assumed a range of values between 0 and 1:

$$TE = \frac{Y_i}{Y^*} = \frac{(x_i\beta_i)\times \exp\,(v_i-u_i)}{(x_i\beta_i)\times \exp\,(v_i)} = \exp\,(-u_i) \tag{6}$$

The empirical model of the stochastic production frontier and the exact variables included in both the basic production model and the inefficiency model for food crops (maize, cassava and okra) were specified below[22]:

$$LnY_i = \beta_0+\beta_1 \ln X_1+\beta_2 \ln X_2+\beta_3 \ln X_3+\beta_4 \ln X_4+\beta_5 \ln X_5+V_i-U_i \tag{7}$$

Where:

LnY_i = Maize outputs (kg)
X_1 = Ln maize farm size (ha)
X_2 = Ln maize seed (kg)
X_3 = Ln family labour (man days)
X_4 = Ln hired labour (man days)
X_5 = Ln herbicides (litres)

$$U_i = \alpha_0+\alpha_1Z_1+\alpha_2Z_2+\alpha_3Z_3+\alpha_4Z_4+\alpha_5Z_5+\alpha_6Z_6+\alpha_7Z_7+\alpha_8Z_8+\alpha_9Z_9+\alpha_{10}Z_{10} \quad (8)$$

Z_1 = Sex (dummy)
Z_2 = Age of farmers (years)
Z_3 = Years of education (years)
Z_4 = Household size (persons)
Z_5 = Access to credit (dummy)
Z_6 = On-farm income (Naira)
Z_7 = Cropping intensity (crop/ha)
Z_8 = Labour intensity (man-days/ha)
Z_9 = Land-use intensity (index)
Z_{10} = Multiple cropping (dummy)
Z_{11} = Cover crop (dummy)
Z_{12} = Crop rotation (dummy)

Two-stage least square regression model: Two- stage least square regression otherwise known as Instrumental Variables (IVs) regression was estimated to determine the effect of land-use intensification on production efficiency. In this study, we approximated the technical efficiency of food crops for farm production efficiency while the nexus between technical efficiency level and land-use intensification was given by Battese and Coelli[22].

TE is f (L and-use intensification Lui, total land size, labour use, use of fertilizers, manure use, household characteristics, farm level factors, natural factors). While, land-use intensification Lui is f (total land size, labour use, household characteristics, crop types, use of fertilizers, manure use, farm level characteristics, natural factors, crop diversification index):

$$TE_i = \beta_0+\beta_1Lui_i+\beta_2X_i+u_i \quad (9)$$

$$Lui_i = \alpha_0+\alpha_1X_i+v_i \quad (10)$$

Where:
TE_i = Production efficiency
Lui = Land use intensification
X_i = Vector of all explanatory variables in both equations
β_0 and α_0 = Constant terms
β_i and α_i = Coefficient estimates while u and v are the error terms in the models

The first stage equation consists of these sets of dependent and independent variables each for maize, cassava and okra outputs:

Y is land-use intensity (index), X_1 is age of farmers (years), X_2 is years of education (years), X_3 is access to credit (dummy), X_4 is crop rotation (dummy), X_5 is cover crop (dummy), X_6 is inorganic fertilizer (dummy), X_7 is labour intensity (man days/ha), X_8 is maize farm size (ha), X_9 is farm distance (km), X_{10} is access to extension (dummy), X_{11} is cropping intensity (crop/ha) and X_{12} is manure use (dummy).

Also, the variables included in the second stage model are:

Y is technical efficiency level of each food crop TE, X_1 is land-use intensity (index), X_2 is age of farmers (years), X_3 is years of education (years), X_4 is access to credit (dummy), X_5 is crop rotation (dummy), X_6 is cover crop (dummy), X_7 is inorganic fertilizer (dummy), X_8 is labour intensity (man days/ha), X_9 is maize farm size (ha), X_{10} =is farm distance (km) and X_{11} is access to extension (dummy).

Statistical analysis: The instrumental variable (IV) regression is based on the use of instruments one which should be instrumented for the explanatory variable with an endogenous property in the model. To validate the specification of instrumental variable employed in this study, post-tests involving test of endogeneity with robust (score) Chi-square (1) and robust reg. (1,333) as well as a test of over-identification score Chi-square (1) was performed. The result showed that the variable instrumented (land-use intensity) was significant at a 5% level with an R-square value of 0.2372 and an F-value of 0.0918.

On the basis of endogeneity tests, the hypothesis (Ho) is that the variable is endogenous if $p<0.05$. From the tests conducted, robust (score) Chi-square (1) and robust reg. (1,333) tests both have $p<0.0001$, respectively which indicates that agricultural land-use intensification is endogenous. Test of over-identification is hypothesized that a model is invalid if $p<0.05$. This hypothesis (Ho) is rejected since the over-identification test score Chi-square (1) was $p<0.5168$ and it validates the use of the instrumental variable estimation approach.

RESULTS AND DISCUSSION

Result of socio-economic characteristics of the selected food crop farmers: Based on the descriptive finding 89.88% of the respondents were males while the rest (10.12%) of them were females. This indicated that male respondents are more involved in farming relative to their female counterparts, which is possibly due to the tedious nature of farm work as shown in Table 1. In line with this result, about 92.0% were found to be male farmers reported by Omotesho *et al.*[23]. It was also found that 41.62% of the farmers were within the age of 41-50 years, 26.59% of them fell between the age of 51-60 years, 17.92% were within the age of 31-40 years, 12.43% reached 60 years and more, while the remaining (1.45%) of them were between the age of 30 years or less. The mean age of farmers was 49.38 years, which implies that the farmers are still within the middle age group. It suggests that at this age, the farmers can make the best decisions that will enhance agricultural intensification practices and their production efficiency levels.

The result revealed that 86.13% of the respondents were married while the rest (13.87%) were single. It means that the married farmers were higher relative to single ones. The economic implication is that rural women are fond of rendering help to support men on-farm activities, for instance, the major roles played by women in agriculture are inevitable, especially during harvesting[24]. Also, the result was tallied with the findings of Abatemarco[25] and Idumah *et al.*[26]. Household size distribution revealed that 50.87% of the respondents have a household size of between 6 and 10 members, 43.64% of them had household sizes of 5 members or less while the rest (5.49%) of them had household sizes of 10 or more members in their households. The average household size is about 6 persons which implies a relatively large size of household members whom they have to cater for. This study also viewed that these family members will supply additional farm labour. It agreed with the study of who observed that the farmers have an average of 6 persons per household. In addition, about 44% of the sampled farmers spent 6 years or less in school, 32.66% of them spent between 7 and 12 years in school and 23.12% of the farmers spent more than twelve years (>12). However, the average year of education was 9.02 years, this finding signified that the farmers are able to read and write since most of them have acquired post-primary education. This finding was consistent with Ehirim *et al.*[27], who observed that the mean formal education attainment is 9.5 years.

The experience level showed that 46.53% had between 6 to 15 years of farming experience, 34.11% of them had 16 to 25 years of experience, 8.38% had 5 or less years of experience and 7.80% had 26 to 35 years of farming experience while the remaining 3.18% had above 35 years of farming experience. The mean farming experience was 17.39 years which suggested that farmers are acquainted with food crop cultivation. This is comparable to the findings by Lawal *et al.*[28] wherein the mean Fadama farming experience was about 17.5 years. Results in Table 1 showed that 45.95% had 5 ha or less as their farm size,

Table 1: Socio-economic characteristics of the food crop farmers

Sex	Frequency	Percentage	Mean
Male	311	89.88	
Female	35	10.12	
Age group			
<30	5	1.45	49.38
31-40	62	17.92	
41-50	144	41.62	
51-60	92	26.59	
>60	43	12.43	
Marital status			
Single	48	13.87	
Married	298	86.13	
Household size			
<5	151	43.64	6
6-10	176	50.87	
>10	19	5.49	
Years of education			
<6	153	44.22	9.02
7-12	118	32.66	
>12	80	23.12	
Years of experience			
<5	29	8.38	17.39
6-15	161	46.53	
16-25	118	34.11	
26-35	27	7.80	
Above 35	11	3.18	
Farm size			
<5	159	45.95	7.67
6-10	109	31.50	
>10	78	22.54	
Primary occupation			
Non-full time farmers	29	8.38	
Full-time farmers	317	91.62	
Farmers' association			
No	31	8.96	
Yes	315	91.04	
Labour source			
Family labour	13	3.76	
Hired labour	134	38.73	
Both hired and family	188	54.34	
Others	11	3.08	
Extension services			
No	75	21.68	
Yes	271	78.32	
Total	346	100	

Field survey data analysis, 2020

31.50% had between 6 and 10 ha and 22.54% had 10 ha or more as farm size. The average farm size was 7.67 ha. The majority (91.62%) of the respondents solely engaged in farming activities, therefore, the study suggested that most of the rural dwellers are still relied on farming activities in order to live and it also evident that agriculture remains the backbone of livelihood security[29].

The study identified further that the majority (91.04%) of the farmers were members of farmers' associations. This indicated that most farmers have a sense of belonging and social relationships amongst other people in the community which may strengthen their collective participatory roles, especially during farming activities. The result also showed that over half (54.34%) of the farmers used both hired and family labour, 38.73% of them used only hired labour, 3.76% used only family labour and 3.08% sourced farm labour from other means like casual or exchange labour. This implied that the majority of the farmers

Table 2: Distribution of food crop farmers based on their access to land

Access to land	Frequency	Percentage
Family inherited land	253	73.12
Rented land	163	47.11
Leased land	7	2.02
Purchased land	56	16.18
Gifted land	29	8.83
Government land	12	3.47
Communal land	4	1.16
Borrowed land	94	27.17
Shared cropping land	42	12.14
Squatted land	2	0.58

Field survey data analysis, 2020 and multiple responses

Table 3: Distribution of crop farmers based on conservation measures adopted

Land conservation measures	Frequency	Percentage
Green manure	161	46.53
Crop rotation practice	262	75.72
Animal waste	50	14.45
Planting cover crop	95	27.46
Use of ridges	215	62.14
Inorganic fertilizer	191	55.20
Minimum tillage	3	0.83
Zero tillage	0	0.00
Agro-forestry practice	11	3.18

Field survey data analysis, 2020 and multiple responses

employed both family and hired labour for their farming activities contrarily, evidence revealed that the majority (79.5%) used hired labour on their farms. About 78% of the farmers have access to extension services while 21.68% do not have access to extension services. It is believed that the works of extension agents are recognized in rural areas, particularly in dissemination of agricultural innovations and skills for improvement in farming operations. Literatures have emphasized more on the positive contribution of this body in agriculture[30].

Modes of accessing land by the respondents: In view of the result shown in Table 2, the trend of the modes of accessing land identified with the food crop farmers is exactly what is happening to the land acquisition patterns in the majority of the rural communities in Nigeria, particularly the Southwest. This result showed that a significant number of farmers used inherited, rented and borrowed farmlands for growing food crops while a few of them accessed land through purchased, shared cropping, government sources and the like. It is implied that most farmers can easily acquire land through several means but that inherited, rented and borrowed farmland access is much more common. This study explained why agricultural land is a little bit inaccessible since a plausible number of the farmers depend on family land so other people who are non-indigenous are more likely to be affected by land ownership. The finding is also evident that the government and other land owners are still putting land under tenure since a majority of the farmers lack access to land, especially the government, lease and communal land sources. The implication of this is indirectly the low supply of food.

Land conservation measures practiced by the food crop farmers: The use of land conservation measures is essential for the purpose of improving soil fertility under intensification or consecutive cropping systems. Table 3 shows the distribution of respondents based on the application of land conservation measures in the study area. The study identified the various land management measures used by food crop farmers and it was found that farmland conservations such as crop rotation, use of ridges and inorganic fertilizers as the most important ones for the farmers to raise potential crop production.

Table 4: Quantities of food crops produced per season in kilograms

Food crop	Observation	Average value (kg)	Standard deviation	Minimum	Maximum
Maize	346	8846.697	13124.65	300	125000
Cassava	346	31084.20	119682.9	150	2080000
Vegetable (okra)	346	18963.79	54668.04	1000	920000

Field survey data analysis, 2020

Table 5: Distribution of the respondents by cropping patterns

Cropping pattern	Crop combination	Frequency	Percentage
Maize/cassava/okra	3 crops combination	237	68.50
Maize/cassava/okra/yam	4 crops combination	74	21.38
Maize/cassava/okra/yam/cowpea	>4 crops combination	35	10.12

Field survey data analysis, 2020 and average of 3 crops combination

Table 6: Distribution of the respondents by variable inputs used

Variable inputs used	Frequency	Percentage
Improved planting materials	305	88.15
Fertilizer	346	100
Pesticides	346	100
Herbicides	346	100
Organic manure (animal waste)	23	6.65

Field survey data analysis, 2020

Quantities/outputs of the food crops per production: Tabulation of the summary statistics of outputs of the selected food crops is presented in Table 4. This finding showed that the farmers harvested an average quantity of 8846.697 kg from maize plots, 31084.20 kg from cassava plots and 18963.79 kg of okra output per season, respectively. Their standard deviations are 13124.65, 119682.9 and 54668.04 for maize, cassava and okra, respectively.

Cropping pattern adopted by the food crop farmers (respondents): The majority (68.5%) of the food crop farmers adopted three crops combinations in order of maize/cassava/okra, while 21.38% of them adopted four crops combinations which included maize/cassava/okra/yam and the rest (10.12%) adopted more than 4 crops combination that is maize/cassava/okra/yam/cowpea. It is signified that farmers planted an average of 3 crops on a piece of land as shown in Table 5. The result further indicated that the majority of the smallholder farmers were involved in multiple cropping in order to prevent total crop loss and unforeseen circumstances.

Variable inputs used by food crop farmers (respondents): The result in Table 6 revealed that all (100%) of the farmers applied fertilizers, pesticides and herbicides for food crop production, respectively, 88.15% used improved planting materials, while 6.65% used organic manure (animal waste) in their farms. This finding examined the rate of application of some variable inputs by the farmers and it was observed that the use of inorganic chemicals is more rampant than the organic fertilizer and many of them used improved planting materials. It is therefore advisable for farmers to have sets of these farm inputs at their disposal for sustainable agricultural land-use intensification.

Measurement of land-use intensity based on rothenberg index: In Table 7 as shown below, the Rothenberg index estimates the land-use intensity of individual farm plots. It was revealed that the farmers practised agricultural land-use intensification with an average value of the intensity of land-use approximately R = 80% while, 3.18, 19.65 and 77.17% of them were at low ($R<33\%$), medium ($33\leq R\leq 66\%$) and high ($R>66\%$) land-use intensities respectively. This implied that the majority of food crop farmers hardly put their farmland on a rotational fallow system. This result was in line with the finding by Alawode *et al.*[31], who found that the majority (70.0%) of the farmers had an index of 1 which means complete land intensification (continuous cropping on the same piece of land every year). On the contrary, an average agricultural land-use intensification index of 0.4174 was obtained among farmers by Akpan *et al.*[32].

Table 7: Distribution of respondents according to land-use intensity

Land-use intensity	Frequency	Percentage
Low land-use intensity	11	3.18
Moderate land-use intensity	68	19.65
High land-use intensity	267	77.17
Total	346	100

Field survey data analysis, 2020, mean value = 79.57%, Ruther berg index, **R<33%: Low land-use intensity, 33 R 66%: Moderate land-use intensity and R>66%: High land-use intensity

Table 8: Distribution of respondents based on technical efficiency in maize, cassava and okra production

Technical efficiency levels	Maize	Cassava	Okra
≤0.49	48 (13.87)	112 (42.77)	41 (11.85)
0.50-0.69	42 (12.12)	80 (23.12)	70 (20.23)
0.70-0.89	112 (32.37)	113 (32.66)	88 (25.43)
0.90-1.00	144 (41.62)	5 (1.45)	147 (42.49)
Total	346 (100.00)	346 (100.00)	346 (100.00)

Field survey data analysis, 2020, hints: Figures tabulated are frequencies, figures in parentheses are percentages, minimum 0.011, maximum = 0.999 and mean= 0.7788 (maize), minimum 0.041, maximum = 0.919 and mean= 0.5492 (cassava), minimum 0.098, maximum = 0.999 and mean= 0.7872 (okra)

Levels of farm-specific technical efficiency for food crops (maize, cassava and okra): The result of efficiency distribution for maize farms in Table 8 showed that the farmers operated at varying efficiency levels with the minimum and maximum efficiency scores of 0.011 and 0.999, respectively. About 41.62% of maize farmers attained technical efficiency level ranging between 0.90 to 1.00, 32.72% operated at a range of technical efficiency of 0.70 to 0.89 and 13.87% of them operated at an efficiency level of 0.49 or less while 12.12% of them were with least efficiency scores (0.50 to 0.69). The mean technical efficiency score among the sampled farmers was 0.7788. It signifies that maize farmers achieved a high efficiency level though not fully efficient and there is a chance for improvement in technical efficiency by 0.2212 with the level of the given technology. The efficiency levels of farmers for the minimum and maximum estimations are 0.041 and 0.919, respectively under cassava. Most (42.77%) farmers operated at 0.49 or less technical efficiency level, 32.66% were found to be 0.70 to 0.89 and 23.12% of them operated at 0.50 to 0.69 while the rest (1.45%) was 0.90 to 1.00 technical efficiency levels. The mean technical efficiency score of cassava farmers was 0.5492. This implies that they are not fully efficient and there is room for improvement in technical efficiency by 0.4508 with the level of the available technology. The distribution of technical efficiency level for okra farm is also presented in Table 8 and the minimum and maximum efficiency scores were found to be 0.098 and 0.999. The highest percentage (42.49 %) of farmers operate at a range of 0.90 to 1.00 technical efficiency level, 25.43% operate at a range of technical efficiency of 0.70 to 0.89 and 20.23% of them operate between the ranges of 0.50 to 0.69 technical efficiency while 11.85% of them achieved the least efficiency scores of 0.49 or less. The mean technical efficiency score among the okra farmers was 0.7872. This signifies that they are not fully efficient and the farmers can improve in technical efficiency by 0.2128 with the level of given technology.

Estimates of stochastic frontier production function for food crop farms: The result exhibited that all variables except the hired labour variable are significant and have positive signs suggesting that more output would be obtained from the use of additional quantities of these variables in the case of maize ceteris paribus. The coefficient of farm size for maize was positive and statistically significant at a 1% level as shown in Table 9. The coefficient of maize seeds was also positive and significant at 1% implying that the addition of more of these seeds would improve the maize output. The output of maize with respect to family labour had a positive sign and was statistically significant at 1%. The positive sign, however, could explain the relevancy of family labour in reducing production costs and improving efficiency of individual maize plots. The quantity of herbicides applied on maize farms has a positive effect on the level of production and is significant at a 1% level. This suggests that the application of herbicides is not a wasteful exercise rather it enhances maize farm performance.

Table 9: Maximum likelihood estimates of stochastic production frontier (Ln maize, cassava and okra production)

	Coefficient estimates		
Explanatory variables	Maize	Cassava	Okra
Basic production model			
Constant	-0.6883356	9.274896	10.90035
Ln maize farm size	0.4660167***	-0.269539**	0.0381513
Ln maize seeds	0.1733708***		0.0631206
Ln family labour	0.3509743***	0.3572559**	-0.27378**
Ln hired labour	0.0310084	-0.399575***	-0.71863***
Ln herbicides	0.4148116***	0.3240239***	0.19319***
Inefficiency model			
Constant	18.64443	11.3592	-25.32865
Sex	-1.523299	0.613348	-0.6135891
Age	-0.0620189**	-3.033884**	-0.0115517
Years of education	0.051675	0.0003171	0.0511179
Household size	0.104089***	0.0242165	0.1301271**
Access credit	0.83728*	0.7219237	9.790148**
Income	-1.01087***	-0.8872147***	0.8962709
Cropping intensity	-0.0719493	-0.0539739	0.055329
Labour intensity	-2.977774***	-0.1807217	-0.0913307
Land-use intensity	-1.239101	-1.997452**	0.890823
Multiple cropping	-0.9355447**	-0.4902096	0.70384
Cover crop	-0.0905599	-1.475248***	1.515452***
Crop rotation	0.1758845	-1.342305*	1.405384
Sigma-square	0.70881	1.154408	0.8942845

Field survey data analysis, 2020, Statistical significance levels: ***1%, **5% and *10%

In addition, for the inefficiency model, the set of significant variables include age of farmer, household size, access to credit, farm income, labour intensity and multiple cropping which means that these variables are drivers of inefficiency of farmers. The age of farmers has an inverse relationship with inefficiency and is significant at 5% indicating that the increase in the age of farmers would lead to a decrease in farm inefficiency. It is also evident that the farmers are technically efficient as they are aged. Household size has a positive coefficient and as well significant at 1% level which implies that the farmers with large household sizes tend to be more inefficient than the farmers with smaller household sizes. Access to credit is positively related to farmers' inefficiency and significant at a 10% level. This result shows as the farmers get more access to loans their technical efficiency level tends to decline, this might occur due to lack of collateral security and mismanagement of obtained credit. It was not in line with a priori expectation.

The income realized by the farmers has a negative association with inefficiency among the farmers and is statistically significant at 1%. It further indicates that more income earned tends to improve the technical efficiency level. Labour intensity which is the area of land per man days negatively affects the technical inefficiency of farmers but significant at a 1% level. This finding indicates that intensive farm labour use is important to enhance farm output/efficiency. Lastly, the coefficient of multiple cropping practices among maize growers has an indirect relationship with inefficiency and is significant at a 1% level, it signifies that multiple cropping practices will improve technical efficiency. In respect to the results of the stochastic frontier analysis for cassava farm operated by food crop farmers, all explanatory variables cassava farm size, hired labour, family labour and quantity of herbicides were significant in the production model. It was found that cassava farm size has a negative sign and is significant at 5%. It signifies that as the additional farm size is put into the cassava crop, the final output obtained becomes low. This situation might arise due to the poor quality of farmland, which consequently leads to low productivity. The coefficient of hired labour is negatively related to cassava output and significant at 1% implying that the use of more hired labour may increase the cost incurred on cassava farming. However, family labour significantly and positively affects the cassava output meaning that an increase number of family labour used for cassava production will result in an increase in output in long run. This result also showed that the quantity of herbicides applied has a positive indication on the production level of cassava crops. It implies further that more use of herbicides will get rid of cassava pests out on the farm site therefore improving the output.

The inefficiency analysis revealed that the age of farmers, income earned, land-use intensity and planting of cover crops determined the level of inefficiency. This finding exhibits that the age of farmers, income, land-use intensity and planting of cover crops had negative coefficients and were significant in the model. It, however, implies that an additional increase in the age of farmers, income, land-use intensity and planting of the cover crop would remove the inefficiency of farmers and make them technically efficient ceteris paribus. Therefore, the finding suggests that income earned, land-use intensity and planting of cover crops are important variables in enhancing cassava out.

The MLE obtained for okra farm revealed that hired labour, family labour and quantity of herbicides are significant factors. The results implied that farmers can increase their output by increasing the number of herbicides used while making use of additional labour either family or hired is capable of decreasing farmers' output of okra. In terms of the inefficiency model, it was found that household size, access to credit and planting cover crops were positively associated with the level of technical inefficiency of the okra farms. It was evident that a large household size would cause more farms inefficient therefore reducing technical efficiency. Furthermore, the result also indicates that technical inefficiency grows among the farmers with more access to credit. This was not in line with a priori expectations. The expectation is that the farmers who have good access to credit should be efficient every other thing being equal.

Results of two-stage least square 2SLS or instrumental variable (IV) regression: The study analyzed the relationship between agricultural land-use intensification and technical efficiency of food crops (maize, cassava and okra) using 2SLS regression Table 10. In the first stage, the findings showed that years of education, access to credit, cover crop planting, inorganic fertilizer, access to extension services and manure use drive agricultural land-use intensification. Years of education, access to credit and cover crop planting is negatively associated with land-use intensity and significant at 1, 10 and 5%, respectively. It signified that the agricultural land-use intensity will be on the decrease when education, access to credit and cover crop planting are increased. It was further found that inorganic fertilizer, access to extension services and manure use related positively with land-use intensity and they were significant at 1 and 5% levels. This finding indicates that land-use intensity increases with more inorganic fertilizer application, access to extension services and manure use. This is in line with a priori expectation since inorganic fertilizer use, access to extension services and manure use among others are close indicators of agricultural land use intensification based on the growing literature.

Consistently, at the second stage of IV regression, the variable instrumented (land-use intensity) entered the model as an exogenous variable and the result showed that farm technical efficiency level is predicated on land-use intensity (5%), cover crop planting (5%) and labour intensity (1%). It is evident that land-use intensification, cover crop planting and labour intensity would improve the technical efficiency of food crop farmers in the study area. Similarly, for cassava crops, year of education, access to credit, cover crop planting, inorganic fertilizer, access to extension services and manure use are determinants of agricultural land-use intensification. Moreover, the second stage regression revealed that land-use intensity related positively to cassava farm efficiency and was significant at (5%), meaning that the efficiency of cassava farms tends to improve as land-use intensity increases. Also, the age of farmers (1%) and years of education (10%) influenced the technical efficiency of cassava farms in the study area. Based on the result, crop rotation practice (1%), cover crop planting (1%) and farm distance (10%) are significantly and negatively determined efficiency levels.

Table 10: Effect of land-use intensity on technical efficiency of food crops using instrumental variable (IV) regression

	Parameter estimates		
Land use intensity	Maize	Cassava	Okra
First stage			
Constant	-0.924967	0.7343399	0.7310954
Age of farmers	0.0002397	-0.000074	-0.0000221
Years of education	-0.0034816*	-0.0043251**	-0.0042868**
Access to credit	0.0674387***	-0.0644719***	-0.0657113***
Crop rotation	-0.0021134	-0.0044581	-0.0039591
Cover crop	-0.0465379**	-0.0405853*	-0.0406695*
Inorganic fertilizer	0.1201013***	0.1190058***	0.1184558***
Labour intensity	0.0023546	0.0076605	0.0074854
Maize farm size	-0.0055278	0.00134	0.0005737
Farm distance	0.002471	0.0006354	0.0007659
Access to extension	0.0711175***	0.0843293***	0.083785***
Cropping intensity	-0.0004758	0.0001357	0.0007437
Manure use	0.0516296**	0.05331251**	0.0535197**
Diagnostic tests			
F-value	2.405 (0.0918)	2.26 (0.1061)	2.41 (0.0918)
R-square	0.2372	0.2372	0.2372
Adjusted R-square	0.2097	0.2098	0.2097
Tests of endogeneity			
Robust (score) chi-square (1)	14.45 (0.0001)	5.375 (0.0204)	1.289 (0.2561)
Robust reg. (1,333)	16.07 (0.0001)	5.342 (0.0214)	1.237 (0.2667)
Test of over-identification			
Score chi-square (1)	0.420 (0.5168)	1.837 (0.1753)	0.8994 (0.3429)
Second stage			
Technical efficiency	Maize farm	Cassava farm	Okra farm
Constant	-0.924967	-0.5723273	1.524542
Land-use intensity	1.922549**	1.292511**	-0.4954033
Age of farmers	0.002932	0.0032531***	-0.0006658
Years of education	0.002932	0.0059995*	-0.0054317***
Access to credit	0.093324	-0.0217913	-0.3369505***
Crop rotation	-0.006449	-0.1371315***	-0.0376252**
Cover crop	0.117294**	-0.107683***	-0.1864203***
Inorganic fertilizer	-0.1440325	-0.0337502	0.0593093
Labour intensity	0.064813***	0.0241597*	0.0127642*
Maize farm size	-0.0071222	0.0034782	0.0044989
Farm distance	-0.0068972	-0.0044612*	-0.0038056***
Access to extension	-0.0144299	0.0374264	-0.0312908

Field survey data analysis, 2020, Significant: ***1%, **5% and *10%

In the case of okra outcome, the finding established that years of education (5%), access to credit (1%), cover crop planting (10%), inorganic fertilizer (1%), access to extension services (1%) and manure use (5%) are significant predictors with respect to agricultural land-use intensification. However, the second stage model estimated that okra farm technical efficiency level is dependent on years of education (1%), credit access (1%), crop rotation (5%), cover crop planting (1%), labour intensity (10%) and farm distance (5%) while the variable instrumented (land use intensity) is not significant. In accordance with the earlier submission, land-use intensity (variable instrumented) supposed to be significantly influence farm technical efficiency whereas it does not, though it has a positive sign. This situation might arise due to the crop type and consumption of the crop by people. The crop is a vegetable fruit crop unlike the other two food crops compared with in this study. Obviously, years of education is indirectly related to the efficiency of okra farms indicating that as years of education increases the efficiency of okra farm decreases. Credit access was found to have an inverse relationship with farm efficiency meaning that as the farmers are opened to various means of obtaining credit/loan the efficiency of okra farms decreases. Similarly, the

Table 11: Distribution of smallholder farmers by constraints facing food crops production

Constraints of smallholder farmers	Frequency	Percentage
High price of farm input	254	73.41
Limited access to land/land tenure effect	223	64.45
Market fluctuation/instability	227	65.61
Problem of agric produce homogeneity	233	67.34
Climatic shocks	183	52.89
Damage from pests and diseases	190	54.91
Water logging/flooding	131	37.86
Shortage of farm labour	299	86.42
High cost of transportation	249	71.97
Lack of modern storage equipment	260	75.14
Soil infertility/land degradation	185	53.47
Lack of capital/credits	251	72.54
Fire outbreak	171	49.42
Fulani herds men crisis	129	37.28

Field survey data analysis, 2020 and multiple responses

practices of crop rotation and cover crops have been detected to lower the efficiency of the food crop farmers. These findings are unexpected. The coefficient of labour intensity has an expected sign (positive) and significantly affected the farm efficiency. It implies that as the farmers utilize more labour there is a possibility for improvement in their efficiency levels. The inverse relationship occurs between farm distance and farm efficiency level which means that the farther away the farm site from home the more the inefficiency among farmers.

Constraints associated to food crops production in the study area: The major farm constraints were identified in Table 11 after completion of field survey exercise. It was discovered that farm labour scarcity was the most pressing challenge faced by the smallholder farmers as reported by 86.42% of them. The implication of this is that the supply of labour for agricultural production is low which in turn causes food insecurity. The percentages of farmers 75.14% were faced with a lack of storage equipment, 73.14% were faced with a high price of input and 72.54% of respondents were faced with financial constraints which implied that several people have limited access to credit facilities in the study area. Access to financial resources by smallholders remains a daunting challenge in African countries[33]. Also, 71.97% were faced with high cost of transportation, 67.34% were faced with agricultural produce homogeneity constraint, 65.61% were faced with market instability, 64.45% were faced with limited access to land, 54.91% were faced with damages from pests and diseases, 53.47% were faced by soil infertility, 52.89% were faced by poor market demand for farm produce, 49.42% were faced by fire outbreak, 37.86% were faced by flooding while 37.28% were faced by Fulani herd men crisis. This indicated that the majority of the farmers were constrained with labour. Smallholder farmers' productivity and growth are hindered by limited access to credit facilities[34].

Experimenting with the endogenous relationship between agricultural land-use intensification and farm production efficiency should be a topic of growing debate in the context of sustainable agricultural development and land-use policy. Based on these findings, the following recommendations were raised for future implementation.

Socio-economic factors: Examining the impact of socio-economic factors on agricultural land-use intensification and farm production efficiency can help to address the challenges of imbalances in food production, market access and population pressure on agricultural land use in the nation. This can provide reasonable suggestions to policymakers in monitoring man-land ratio and production efficiency.

Foster optimization of farm resources uses: Farm resources such as land use, labour and capital are essential inputs in measuring the performance of agricultural land-use intensification and farm production efficiency. So, addressing the farmers' means of accessing these agricultural inputs is important to facilitate farm work and enhance food production.

Strengthen agricultural extension services: Enhance the capacity and reach of agricultural extension services to provide farmers with up-to-date information, technical assistance and training on best farming practices. It will be useful for targeted government intervention and programs dealing with the roles of extension workers on agricultural land-use intensification and efficiency of farm set-up.

Farmland conservation practices: Analyzing agricultural land-use intensification and efficiency of food crop farming supports adequate farmland conservation practices among farmers, which include the application of modern and traditional land conservation practices to enrich soil composition for improved land productivity. It is recommended that agricultural stakeholders incorporate farmland conservation into their plans for the farming system.

Overall, agricultural land-use intensification permits forestland and ecosystem conservation by lessening the area of land that is exposed to deforestation and desertification each year through agriculture. Understanding the land-use intensification patterns can help in identifying areas where there is a need for conservation, sustainable land-use practices, or land restoration efforts. It can contribute to spatial planning that balances agricultural production with the preservation of critical ecosystems, biodiversity and water resources. Also, the findings of the study can inform the development of agricultural land-use policies and plans at regional and national levels. Policymakers can then use the insights gained to design targeted interventions to ensure efficient land use patterns and maximize agricultural productivity.

CONCLUSION

The findings imply that the majority of the selected food crop farmers were males and middle-aged, most of them were married and they have large household sizes. Farmers planted an average of 3 crops (maize/cassava/okra) on a piece of land and their mean farm size was 7.67 ha. Most of the farmers relied on inherited farmland while the commonest labour source was the hired versus family labour type. Empirically, the result showed that food crop farmers practiced continuous land cultivation which is an indication of high land-use intensity and low farmland fallow. It was also observed that the level of farm-specific technical efficiency attained by the farmers is still below the production frontier so, farmers should try more to cover the gaps in food production. Land-use intensity and labour-use intensity significantly enhanced maize farms' efficiency level. Similarly, efficiency in cassava farms was improved by land-use intensity, labour-use intensity, age of farmers and years of education while okra was significantly improved by labour-use intensity. The study identified further that shortage of farm labour, lack of modern equipment, the high price of farm input and lack of credit were the main constraints fighting against efficient food crop production. The study hence concluded that production efficiencies among smallholder food crop farmers were improved by land-use intensities for maize and cassava and by extension access, years of education, age of farmers and labour-use intensity. In view of the findings, policy intervention on agricultural land-use intensification, access to extension service delivery, education, the middle-aged and supply of farm labour are recommended in order to improve efficiency among food crop farmers.

SIGNIFICANCE STATEMENT

The efficiency stage in food crop production is given priority as a decision-making unit, but unfortunately in most developing nations, its attainment is hampered by poor conditions of farm operation and shortage of resources among others. Sustainable agricultural intensification also remains the paradigm to promote agriculture in a period of burgeoning food demand and deteriorating resources. As a matter of fact, this article tried to investigate the endogenous attributes of agricultural land-use intensification and production efficiency for the purpose of designing scientific inferences about them. Based on the study, it is proven that agricultural land-use intensification practices can create positive change in farm production efficiency in developing countries.

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