ANALYSIS OF TECHNICAL EFFICIENCY OF MAIZE-BASED CROPPING SYSTEMS AMONG SMALL SCALE FARMERS IN ADAMAWA STATE, NIGERIA

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Abstract: Maize is a staple food of many households in Nigeria and its production comes under different cropping systems. This study analyses technical efficiency of maize-based cropping systems among small scale farmers in Adamawa State, Nigeria. A multi-stage random sampling technique was used to select 310 maize farmers from eight Local Government Areas of the State using structured questionnaires. Descriptive statistics, such as means and percentages were used to describe the socio-economic characteristics of the farmers and their different maize-based cropping systems, while the stochastic production frontier model was used to determine the technical efficiency of the farmers. The results revealed that majority (68.08%) of the respondents were male with mean age of 47 years. The mean household size was 8 with 77.42% possessing varied levels of formal education. Maize intercropped with other crops was the dominant (73.11%) cropping system accounting for 56.78% of total area cultivated. Farmers were technically efficient in their production, with mean technical efficiency of 0.73. Education, farming experience and extension contact were significant variables that positively influence technical efficiency. The study recommends among others public investments in education since it has complementary and synergistic effect on improved technical efficiency.

Keywords: Maize, technical efficiency, farmers, cropping systems, Adamawa State

Introduction

Maize is one of the staple food crops in Nigeria, whose production has been a source of livelihood to many resource poor farmers. Nigeria is the largest producer of maize in Africa where about 70% of the farmers are small scale farmers and produce about 90 percent of total farm output (IITA, 2012; Cadini and Angelucci, 2013). In sub-Saharan Africa, maize is a staple food for an estimated 50% of the population where about 80% of it is consumed, while 20% is utilized in a variety of industrial processes for the production of starch, corn sweetener, ethanol, cereal and alkaline (Owaeye, 2017). Maize production in Nigeria has risen to commercial scale where it provides raw materials to many agro-based industries (Iken, and Amusa, 2014).

In Nigeria, more than 50% of the annual maize production is used to produce animal feeds and most of the Nigerian farmers are involved in its cultivation, processing and marketing (Samade, 2016). The country has a total arable land of about 98.3 million hectares, of which only 40% is under cultivation (FMARD, 2001; Omorogiuwa *et al*., 2014). Ironically, domestic food demand in the country has outstripped food supply over the years resulting in wide food deficits leading to large scale food importation (Ogundari and Ajibefun, 2006; CBN, 2016). The low productivity of maize is attributed to the bulk (90%) of the country's farms relying on subsistence agriculture which involved the use of rudimentary tools, low capitalization and low yield per hectare (Ogundari *et al*., 2006).

The achievement of food self-sufficiency therefore has been the policy thrust of successive governments in Nigeria. In view of the growing gap between the demand for and supply of food in the country against the background of an increasing population, the efficiency with which available resources and technology are used by farmers becomes a priority subject of investigation (Maurice *et al*., 2014). It is no surprise therefore, that considerable effort has been devoted to the analysis of farm level efficiency in developing countries. Efficiency studies are important in that they serve as reliable guidance in formulating policies, especially when it comes to the search for the primary causes of inefficiency and improvement potentials (Ogundari *et* al. 2011). Efficiency analysis is an issue of interest given that the overall productivity of an economic system is directly related to the efficiency of production of the components within the system.

It is concerned with the economic performance of the processes used in transforming given inputs into outputs. Technical efficiency measures the relationship between the physical quantities of inputs and output. In other word, technical efficiency determines the maximum possible output using the same input mix or different combination of resources (Ogbanje *et al.*, 2014). Formally, the level of technical efficiency is measured by the distance of firm from the optimal production frontier. A firm that sits on production frontier is said to be technically efficient.

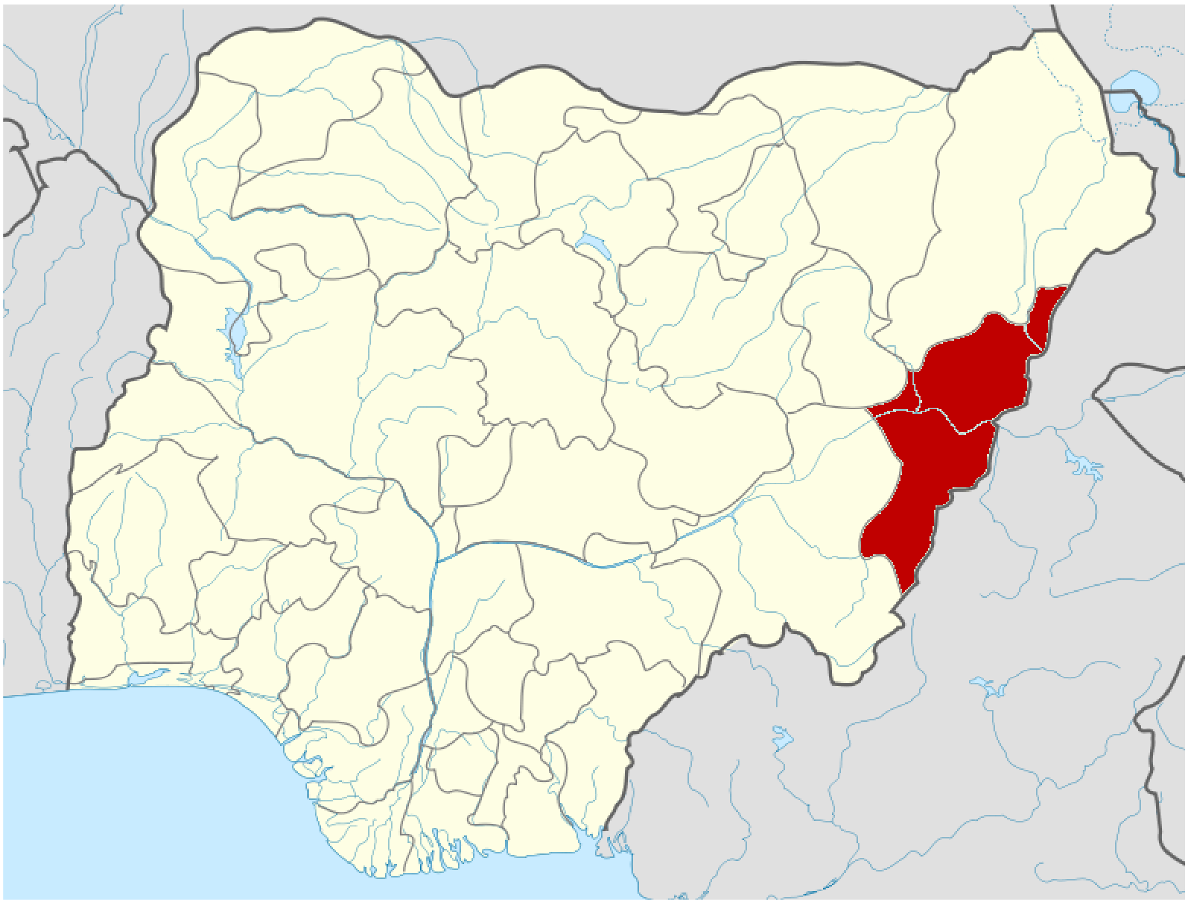
Increased productivity gain have in general decreased food cost and improved food security, particularly for vulnerable section of the society (Haruna and Sani, 2010); therefore, food crop farmers need to be more efficient in their production activities and be also responsive to market indicators, so that scarce resources are utilized efficiently to increase production as well as productivity in order to ensure continuous food supply. This will have a multiplier effect on the livelihood and income of the large resource poor farmers in the State. The efficiency indices computed reveal the extent of technical efficiency among small holder farmers. This reflects the existing potential for farmers to improve output without changing the level of inputs or produce the same output with far less inputs than they are currently using. Farmers characteristics observed among efficient farmers were used to formulate policy recommendations that help policy makers develop strategies to help inefficient farmers.

Materials and Methods

Study area

Adamawa State is located at the North Eastern part of Nigeria and created in 1991 from the defunct Gongola State. It lies between Latitude 7^0 and 11^0N of the Equator and between Longitude 11^0 and 14^0E of the Greenwich Meridian. It shares boundary with Taraba State in the South and West, Gombe State in the North West and Borno State in the North. Adamawa State has an international boundary with Cameroun Republic along its eastern border. The State covers a land area of about 38,741 Km^2 and is divided into 21 Local Government Areas with projected population of 3,675,000

(NPC website, 2015). The State has a tropical climate marked by dry and rainy seasons. The rainy season commences in April and ends in late October. The wettest months are August and September. Mean monthly temperature in the State ranges from 26.7^{0}C in the south to 27.8^{0}C in the north eastern part of the State. The mean annual rainfall ranges from 700mm in the north eastern part of the State to 1600mm in the southern part (Adebayo, 1999a). On the other hand the north eastern strip and the southern part have over 1,000mm (Adebayo, 1999b).



Coordinates 9°20'N 12°30'E

Fig. 1: Location of Adamawa State in Nigeria

Sampling procedure and sample size

Adamawa State is made up of 21 Local Government areas (LGA) divided into four Agricultural zones by the Adamawa State Agricultural Development Project (ADADP) for administrative convenience. Maize is a staple food of many households in the state and is produced in all the Local Government Areas of the State. Multi-stage random sampling technique was employed in the selection of respondents used for the study. In the first stage, two Local Government Areas were randomly selected from each ADP zone. These were Michika and Mubi North LGAs in zone I, Gombi and Girei LGAs in Zone II, Ganye and Mayo Belwa LGAs in Zone III and Guyuk and Demsa LGAs in Zone IV (Table 1). In the second stage, two wards were randomly selected from each of the selected local government to give a total of 16 wards. Third stage involved the random selection of 1 village from each selected ward giving a total of 16 villages. A total of 310 respondents were randomly selected in the sampled villages from the existing sampling frame obtained from the village and ward heads based on proportionality factor as shown in the Table.

Table 1: Distribution of farmers according to selection procedure

AD.ADP Zones	LGAs	Wards	Villages	Sampling frame	Sample size
Zone I	Mubi/N	Mayo-bani	Muva	119	21
		Lokowa	Lira	95	17
	Mubi/S	Lamurde	K/dare	114	19
		Nasarawo	Gella	103	21
Zone II	Gombi	Gombi one	Gada/M	77	13
		Ganda	Parijo	100	17
	Girei	Damare	Damare	119	20
		Girei one	Girei	120	24
Zone III	Mayo/B	Ribadu	Sangere	101	20
		Jereng	Yolde/G	60	11
	Fufore	Beti	Wuro/M	120	21
		Gurin	Muninga	122	20
Zone IV	Guyuk	Bajaram	Pondiwe	114	19
		Lokoro	Lakumna	109	19
	Demsa	Dwam	Dwam/S	151	29
		Dong	Dong	110	19
Total				1734	310

Source: Field Survey, 2015

Data collection

Primary data were used for the study and were collected using well structured questionnaires. The data collected were based on the 2015 cropping seasons.

Model specification

The explicit form of the stochastic frontier production model is specified thus:

$$lnY_{ij} = \beta_0 + \beta_1 lnX_{1ij} + \beta_2 lnX_{2ij} + \beta_3 lnX_{3ij} + \beta_4 lnX_{4ij} + \beta_5 lnX_{5ij} + \beta_6 lnX_{6ij} + V_{ij} - U_{ij} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where: L_n = Logarithm to base e; Y_i = Output of food crops (grain equivalent weight); X_1 = Farm size (ha); X_2 = Family labour (in mandays); X_3 = Hired labour (in mandays); X_4 = Agrochemical (Litres/ha); X_5 = Inorganic fertilizer (kg/ha); X_6 = Seeds (kg/ha)

It is assumed that the technical inefficiency effects are independently distributed and U_i arises by truncation (at zero) of the normal distribution with mean, μ_{ij} and variance δ^2, where μ_{ij} is defined by:

$$\mu_{ij} = {}_0 + {}_1Z_{1ij} + {}_2Z_{2ij} + {}_3Z_{3ij} + {}_4Z_{4ij} + {}_5Z_{5ij} + {}_6Z_{6ij} + {}_7Z_{7ij} \quad \ldots\ldots\ldots(2)$$

Where: μ_i = Inefficiency effect; Z_1 = Age of farmer (years); Z_2 = Farming experience (years); Z_3 = Educational level of farmers (years); Z_4 = Household size (Number of people); Z_5 = Extension contact (number of meetings); Z_6 = Crop diversification (1 indicate sole cropping and 0 otherwise)

Results and Discussion

Socio-economic characteristics of the respondents

The socio-economic characteristics of the respondents as presented in Table 2 reveal that majority (87.10%) of them were male, implying that maize-based cropping system is dominated by male. This agrees with the findings of Kefas (2013) who argued that females were mostly involved in farming as helpers or suppliers of labour in light farm operations like planting, weeding, harvesting, food processing and marketing which are not tedious activities compared to farm clearing, digging and threshing among other operations. This result is however at variance with the findings of Maurice (2012) who found that food crop production in the state is dominated by the female. The distribution of the marital status of the respondents reveals that married people were the dominant (67.74%). The implication of this on agricultural production is that, labour supply will be more where the household heads are married. Comparable results were obtained by Nwachuku (2007) and Dary and Kunnibe (2012) who found that 90 percent of food production in this country comes from rural households who are mostly married.

The age distribution shows that majority (96.77%) of the respondents were within the age range of 20-49 years, with a mean age of 47 years. This indicates that the respondents were in their active and productive age bracket, and they will be willing to adopt and practice new technology effectively (Kefas, 2012). This study is in consonance with the finding of Nwalieji and Ajayi (2009) who reported a higher proportion of younger people in adoption of improved production practices. Younger farmers have the tendency to operate more efficiently than the older farmers (Onu and Edon, 2009).

The distribution of the respondents by farming experience reveals that 19.35% of the respondents had farming experience of less than 10 years, while majority (67.74%) of them had farming experience of between 11 and 20 years. The mean farming experience was about 23 years, indicating that the respondents are experienced in maize production. By implication, the more experience the farmers are, the more innovative they will be in terms of practicing new technology. This agrees with studies conducted by Ayaode (2010) who reported that an increase in farming experience increases the probability of a farmer to adapt to climate change and vice versa.

On household size of the respondents, it reveals that about 65% percent of the respondents had household size of up to 1-10 persons; with mean household size of 8 persons. The number of persons in a household is very important in determining the labour availability for farm work. It will also affect household income and expenditure. Thus, household size in the state is fairly large.

The educational level of the respondents reveals that majority (77.42%) of them had some levels of formal education with primary education accounting for 54.52% while tertiary education had the least with 7.74%. This implies that the respondents are literate. Most (67.42%) of them were full time farmers and majority (63.55%) have farm size of not more than 2 hectares. This implies that the respondents are small scale farmers. This is in line with the work of Afolabi (2010) who reported that food production in Nigeria is usually undertaken by small and medium scale farmers. The distribution of respondents based on extension contact reveals a greater number (57%) of them did not have any contact with extension agents in the last 12 months. By implication, it will deny them opportunity of utilizing new technology that could improve their skills and technical know- how, which will improve their productivity.

Table 2: Socio-economic characteristics of maize-based farmers in Adamawa State

Sex	Frequency	%
Male	270	87.10
Female	40	12.90
Marital status		
Single	53	17.10
Married	210	67.74
Divorced	25	8.06
Widow	22	7.10
Age (years)		
20-29	22	7.10
30-39	67	21.61
40-49	211	68.06
50-59	10	3.23
Farming Experience (years)		
≤ 10	60	19.35
11-20	210	67.74
21-30	18	5.81
31	22	7.1
Household Size		
1- 5	80	25.81
6-10	120	38.71
11	110	35.48
Educational Level		
No formal education	70	22.58
Primary education	1629	54.52
Secondary education	47	15.16
Tertiary education	24	7.74
Primary Occupation		
Farming	209	67.42
Civil service	78	25.16
Trading	23	7.42
Farm Size (ha)		
≤ 2.0	197	63.55
2.1-3.9	78	25.16
4.0-5.9	32	10.32
6.0	3	0.97
Extension Contact		
Non	176	56.77
Once yearly	61	19.68
Twice yearly	50	16.13
More than twice yearly	23	7.42

Source: Field Survey, 2015

Maize-based cropping systems

The objective of any cropping system is efficient allocation of all resources (Panda, 2007). The distribution of cropping system of maize –based farmers as presented in Table 3 has revealed seven (7) cropping systems. Sole cropping accounted for 23.87%t, with 35.11% of the total hectarage allocation, while mixed cropping accounted for 76.13%, with 64.89% of the total hectarage allocation. On the area under cultivation, the average area under sole maize was estimated at 3.61 ha which is higher than areas under maize combined with other crops. The distribution reveals that mixed cropping is the common cropping system among the respondents in the area and is due largely to consideration for risk minimization, stable income and adaptability to a particular season (Sani and Haruna, 2010; Maurice *et al*., 2015).

Table 3: Distribution of respondents by maize-based cropping systems

Cropping systems	Respondents		Ha allocation		Average Farm size (ha)
	No.	**%**	**No**	**%**	
Sole maize	74	23.87	267.5	35.11	3.61
Maize/sorghum	11	5.54	31.0	4.07	2.82
Maize/cowpea	168	54.19	384.5	50.47	2.29
Maize/cowpea/sorghum	28	9.03	63.4	8.32	2.26
Maize/groundnut	10	3.22	9.0	1.18	0.9
Maize/cowpea/groundnut	10	3.22	2.0	0.26	0.2
Maize/rice	9	2.90	4.5	0.59	0.5
Total	**310**	**100**	**761.9**	**100**	

Source: Field Survey, 2015

Table 4: Maximum likelihood estimates for parameters of stochastic production Frontier model for maize-based farmers in Adamawa State

Variable	Parameter	Coefficient	t-ratio
Constant	β_0	4.035	48.2859***
Farm size (x_1)	β_1	0.153	2.7605***
Family labour (x_2)	β_2	0.0541	0.5349
Hired labour (x_3)	β_3	0.215	2.6626***
Agrochemicals (x_4)	β_4	0.126	2.2372**
Inorganic fertilizer(x_5)	β_5	0.0153	0.0849
Seeds (x_6)	β_6	-0.0412	-0.8948
Inefficiency effects			
Age(z_1)	Z_1	-6.647	-1.4328
Farming experience(z_2)	Z_2	-0.228	-2.4935**
Education(z_3)	Z_3	-0.164	-2.8678***
Household size(z_4)	Z_4	0.129	1.5705
Extension contact(z_5)	Z_5	-0.144	-2.3128**
Crop diversification(x_6)	Z_6	-0.776	-2.2108**
Diagnostic statistics			
Sigma-squared	δ^2	0.499	2.0665**
Gamma	Υ	0.888	5.3932***

Source: Field Survey, 2015

Result of stochastic frontier production function for maize-based farmers

The maximum likelihood estimates (MLE) of the stochastic production function in explaining the influence of production inputs on the output of maize-based farmers in the state and also in determining the effect of farmers' specific characteristics on the technical inefficiency is presented in Table 4. The result shows that the coefficients of farm size (β_1), hired labour (β_3) and agrochemicals (β_4) are all positive and statistically significant at varied acceptable levels. This implies that a one unit increase in the use of these production inputs will bring about increase in the total output of maize-based production by the respective values of the coefficients. The elasticity of the explanatory variables show decreasing returns to scale (< 1), indicating that the input allocation by these farmers is in stage II of the production function. The sigma squared (0.499) is statistically significant at 5% level. This indicates a good fit and correctness of the distributional form assumed for composite error term. The variance ratio defined as gamma is 0.89 and statistically significant at 1% level, implying that 89% of the variation in the output of the farmers was due to differences in their technical efficiencies. In other word, the existence of technical inefficiency among the farmers accounted for 89% of the variation in the output level of the farmers.

Farm size is positive which conform to *apriori* expectation and significant at 1% level. This implies that a 1% increase in hectare used in maize-based production *ceteris paribus* will bring about increase in the total output by 0.153% and vice versa. This result agrees with Girei (2014) who identified land as a critical factor in agricultural production.

The coefficient of hired labour is positive and statistically significant at 1% level, implying that a 1% increase in man-days of hired labour used in production will bring about increase in maize-based output by 0.215%. According to Audu *et al*. (2009), given the ageing trend of our farmers and high rate of rural-urban migration, the high cost of labour is undesirable.

Agrochemicals which include herbicides and pesticides have an elasticity coefficient of 0.126 and statistically significant at 5% level. This means that a 1% increase in the quantity of agrochemicals used in maize-based crop production would increase output by 0.126%. The use of agrochemicals help farmers to save time and money that would have been spent on weeding and manual control of pest and diseases. This result agrees with the findings of Maurice *et al*. (2015)) who reported that the use of herbicides reduces cost of weeding and also reduces stress and fatigue associated with food crop production. By implication it helps farmers to cultivate large hectares of land which will result in an increase in maize-based output. This agrees with the findings of Okoze *et al.* (2012) who asserted that the use of herbicide reduces drudgery and enable farmers increase their farm size.

The inefficiency parameters were specified as those relating to farmers specific socio-economic characteristics which include age, farming experience, education, house-hold size, and extension contact and crop diversification. A negative coefficient indicates that the variable has positive effect on efficiency and vice versa. The coefficient of farming experience variable is estimated to be negative and statistically significant at 5% level. This implies that farmers with more experience tend to be more efficient in maize-based production than those who are not experienced. This is because experience increases expertise and managerial skills of the farmers. Thus, farmers with more years of farming experience are expected to be more efficient, presumably due to their ability to acquire technical knowledge through learning on the job. This result agrees with the findings of Oladimeji and Abdulsalam (2014) and Mustapha and Musa (2015), who established that increase in farming experience decreases inefficiency among farmers.

The estimated coefficient of education variable is negative and statistically significant at 1% level, implying that farmers with formal schooling tend to be more efficient in maize-based production than illiterate farmers, presumably due to their enhanced ability to acquire technical knowledge which makes them move closer to the frontier output. Also, educated farmers respond easily to the use of improved technology, such as improved seeds, agrochemicals, fertilizer application among others which moves them closer to the frontier output.

The coefficient of extension variable is estimated to be negative and statistically significant at 5% level. This indicates that increase in extension services to farmers tend to increase technical efficiency in maize-based production in the study area. Extension visit help the farmers to learn new technology about agricultural production. A similar result was also reported by Girei (2014) who obtained a significant and positive relationship extension contact and technical efficiency. Crop diversification variable in the model is negative and statistically significant at 5% level. As farmers practice diversification (maize intercropping), the more efficient they become. That is, crop diversification is associated with higher relative efficiency. A similar comparable result was obtained by Maurice (2012) who established that crop diversification contributed to technical efficiency.

Technical efficiency index of maize-based farmers in Adamawa State

The technical efficiency index of the respondents is presented in Table 5. It shows that the technical efficiency of the sampled farmers is less than 1.0, indicating that all the farmers were producing below the maximum efficiency frontier. The farmers' technical efficiency reveals a wide efficiency differential between the best technically efficient farmer (0.94) and the least technically efficient farmer (0.11). The mean technical efficiency is 0.73 indicating that in the short run, there is a scope for increasing technical efficiency among maize-based crop farmer in the study area by 27 percent. Also, the least efficient farmer needs about 83% efficiency improvements to attain the level of the most efficient farmer in the State. The result also shows that majority (82.5%) of the farmers produce above 0.49 efficiency index, while 50.64% of the farmers produce above estimated average technical efficiency of 0.73. As revealed by the result, most of the sampled farmers operated below the production frontier, hence will not be able to maximize their yield per hectare. This will translate to low income and hence low revenue. A similar result was obtained by Egbodion (2012) in a study on comparative technical efficiency among arable crop based and permanent crop enterprise combination in Edo State, Nigeria where a mean technical efficiency of 0.68 (68%) was obtained.

Table 5: Distribution of technical efficiency estimates of maize-based farmers in Adamawa State

Efficiency index	Frequency	Percentage
0.10-0.19	7	2.26
0.20-0.29	10	3.23
0.30-0.39	16	5.16
0.40-0.49	21	6.77
0.50-0.59	14	4.52
0.60-0.69	29	9.35
0.70-0.79	56	18.06
0.80-0.89	141	45.48
0.90-1.00	16	5.16
Mean 0.73		
Minimum 0.11		
Maximum 0.94		

Source: Field Survey, 2015

Conclusion

The stochastic production function results shows that the coefficient of farm size, hired labour and agrochemicals were positive and significantly affect maize-based output of the respondents. The analysis of technical efficiency indicates that there is a scope for increasing technical efficiency in the short-run by 27 percent through efficient utilization of existing inputs under the current state of technology. It is also important to note that respondents' literacy level is high, indicating a departure from the age-long non-formal and illiteracy status of Nigerian farmers. However, the farmers were mostly small-scaled, cultivating not more than 2 hectares of farm land. In addition, male farmers dominated maize-based cropping system in the study area.

Recommendations

Based on the findings of this study, the following recommendations have been put forward:

1) There should be deliberate effort by the government and non-governmental agencies to educate farmers on the utilization of basic agricultural technology through strengthening the extension arm of the Agricultural Development Programmes.
2) Government and non-governmental organizations should encourage and support education at all levels since an educated farmer is more technically efficient than an uneducated farmer.
3) More production incentives such as subsidized farm inputs should be given to farmers through the relevant arms of government so that they can raise their levels of production.

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