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Sources of Technical Efficiency among Smallholder Maize Farmers in Osun State of Nigeria

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Abstract: There have been several attempts by the government to improve the productivity of food crops on small farms, particularly for maize including the development of high yielding maize varieties, subsidization of farm inputs, provision of credit facilities and the liberalization of farm produce prices and marketing. While there have been several studies on Technical efficiency in Nigeria, the focus has mainly been on cassava, rice cocoyam, cowpea and cotton. This study estimates technical efficiency among smallholder maize farmers in Nigeria and identifies sources of inefficiency using plot-level data. The reseachers find that smallholder maize farmers in Nigeria are inefficient. The results of the study reveal that inefficiency declines on plots planted with hybrid seeds and for those controlled by farmers who belong to households with membership in a farmers association.

Key words: Smallholder farmer, technical efficiency, Nigeria, agricultural investment, staple foods

INTRODUCTION

Relative productivity of workers in agriculture has declined as the share of agriculture in Gross Domestic Product (GDP) has steadily gone down whereas the proportion of labour force dependent on agriculture has not changed much (Chatterjee, 1995). Africa's socio-economic development is mainly agrarian and about 70% of the labour force (and 80% of its poor people) are directly or indirectly engaged in agriculture, live in rural areas and depend on agriculture for their livelihood (NEPAD, 2004). Agriculture still remains the mainstay of the economy of most African states, yet a current estimate indicates that some 200 million or 28% of African's population are chronically hungry. According to Olagunju (2005) the agricultural sector is an engine room for sustainable growth of Nigerian economy.

Nigerian agriculture is characterised by considerable regional and crop diversity. Analysis of this sector, particularly the food sub-sector is fraught with serious data problems. In the 1960s, the agricultural sector was the most important in terms of contributions to domestic production, employment and foreign exchange earnings. The situation remained almost the same 3 decades later with the exception that it is no longer the principal foreign exchange earner, a role now being played by oil. The sector remained stagnant during the oil boom decade of the 1970s and this accounted largely for the declining share of its contributions. The trend in the share of agriculture in the GDP shows a substantial variation and long-term decline from 60% in the early 1960s through 48.8% in the 1970s and 22.2% in the 1980s. Despite Nigeria's rich agricultural resource endowment, however the agricultural sector has been growing at a very low rate. <50% of the country's cultivable agricultural land is under cultivation. Even then, smallholder and traditional farmers who use rudimentary production techniques with resultant low yields, cultivate most of this land. The smallholder farmers are constrained by many problems including those of poor access to modern inputs and credit, poor infrastructure, inadequate access to markets, land and environmental degradation and inadequate research and extension services. On its diversity, Nigerian agriculture features tree and food crops, forestry, livestock and fisheries. In 1993 at 1984 constant factor cost, crops (the major source of food) accounted for about 30% of the GDP, livestock about 5%, forestry and wildlife about 1.3% and fisheries accounted 1.2%.

It can be distinguished between smallholder farmers and estate farmers, the latter being large-scale commercial operations. The smallholder sector is divided into three categories: net food buyers, intermediate farmers and net food sellers. Net food buyers are those farmers with <0.7 ha, who cannot produce food to satisfy their subsistence needs given the technology they use and who thus remain dependent on off-farm activities. Intermediate smallholder farmers are those with land holding between 0.7 and 1.5 ha who produce just enough for their survival but have very little for sale. Net food sellers are those farmers with land holdings of >1.5 ha, who produce more than their subsistence needs for survival during the year. Maize is a cereal crop grown in

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all ecological zones of Nigeria. It is generally accepted as a good source of energy for man and livestock. Hence, it has over time evolved as the most staple and choice food for most people in the country. Maize is rich in carbohydrates, starch and protein, fats, among others which make it a very good and reliable source of food, energy, sweetness and industrial raw materials. These outstanding features of maize have prompted its cultivation by many smallholder farmers.

Notable problems of maize production include inappropriate decision on how best to allocate resources, inadequate use of corresponding production inputs and inadequate adoption of improved technologies by farmers. Also farmers might use resources rationally but not at economic optimal level. All these contribute inefficiency. Therefore, it is proper to estimate technical efficiency and identify the factors that explain variations in technical efficiency.

The study has three specific objectives. First, the study estimates mean and plot-specific technical efficiency levels in smallholder farms producing maize. Second, it examines the impact of technology adoption, such as improved seeds and fertilizer application on the technical efficiency of smallholder farmers. Third, the study determines the relative role of farmer education, use of fertilizers, use of hybrid seeds, membership in an association and access to extension services.

Estimating technical efficiency: The literature suggests several alternative approaches to measuring productive efficiency, grouped into non-parametric frontiers and parametric frontiers. Non-parametric frontiers do not impose a functional form on the production frontiers and do not make assumptions about the error term. These have used linear programming approaches; the most popular non-parametric approach has been the data envelopment analysis. Parametric frontier approaches impose a functional form on the production function and make assumptions about the data.

The most common functional forms include the Cobb-Douglas, constant elasticity of substitution and translog production functions. The other distinction is between deterministic and stochastic frontiers. Deterministic frontiers assume that all the deviations from the frontier are a result of firms inefficiency while stochastic frontiers assume that part of the deviation from the frontier is due to random events (reflecting measurement errors and statistical noise) and part is due to firm specific inefficiency (Forsund *et al.*, 1980; Battese, 1992; Coelli *et al.*, 1998). The stochastic frontier approach, unlike the other parametric frontier measures makes allowance for stochastic errors arising from statistical noise or measurement errors. The stochastic frontier model decomposes the error term into a two-sided random error that captures the random effects outside the control of the firm (the decision making unit) and the one-sided efficiency component. The model was first proposed by Aigner *et al.* (1977) and Meeusen and van den Broeck (1977). Assuming a suitable production function, the researchers define the stochastic production frontier as:

$$\text{In}(y_i) = f(x_{ij}, \beta) + \varepsilon_j \quad (1)$$

Where:

y = The level of output on the jth plot
x = The value of input i used on plot
j, ε_i = v_j-u_j the composed error term
v_j = The two-sided error term
u_j = The one-sided error term

The components of the composed error term are governed by different assumptions about their distribution. The random (symmetric) component v_j is assumed to be identically and independently distributed as N (0, σ_v^2) and is also independent of u_j. The random error represents random variations in the economic environment facing the production units reflecting luck, weather, machine breakdown and variable input quality; measurement errors and omitted variables from the functional form (Aigner *et al.*, 1977).

The distribution of the inefficiency component can take many forms but is not symmetric. However, there is no a priori argument that suggests that one form of distribution is superior to another, although different assumptions yield different efficiency levels. The inefficiency component represents a variety of features that reflect inefficiency such as firm-specific knowledge; the will, skills and effort of management and employees and work stoppages, material bottlenecks and other disruptions to production (Aigner *et al.*, 1977; Lee and Tyler, 1978; Page, 1980). Meeusen and van den Broeck (1977) and Aigner *et al.* (1977) assume that uj has an exponential and a half-normal distribution, respectively. Both distributions have a mode of zero. Other proposed specifications of the distribution of uj include a truncated normal distribution -N (μ, σμ2) (Stevenson, 1980) and the gamma density (Greene, 1980). The stochastic model can be estimated by the Corrected Ordinary Least Squares (COLS) method or the maximum likelihood method. The researchers follow the research of Battese and Coelli (1988, 1995) using a Battese and Corra (1977) parameterization. The Maximum Likelihood (ML) estimates of the production function (Eq. 1) are obtained from the following log likelihood function:

$$\text{In}\,L = \frac{N}{2}\text{In}\left[\frac{\pi}{2}\right] - \frac{N}{2}\sigma^2 + \sum_{j=1}^{N}\text{In}\left[1 - F\left[\frac{\varepsilon\sqrt{\gamma}}{\sigma\sqrt{(1-\gamma)}}\right]\right] - \frac{1}{2\sigma^2}\sum_{j=1}^{N}\varepsilon_j^2 \quad (2)$$

Where:

$j\varepsilon$ = Residuals based on ML estimates

N = The number of observations

F() = The standard normal distribution function

$$\sigma^2 = \sigma_u^2 + \sigma_v^2$$
$$\gamma = \sigma u^2/\sigma 2$$

Assuming a half-normal distribution of u, the mean technical efficiency is measured by:

$$E\left[\exp\left(-u_j\right)\right] = 2\left[\exp\left(-\gamma\sigma^2/2\right)\right]\left[1 - F\left(\sigma\sqrt{\gamma}\right)\right] \quad (3)$$

where, F is the standard normal distribution function. Measurement of farm level inefficiency requires the estimation of non-negative error u. Given the assumptions on the distribution of v and u, Jondrow *et al.* (1982) first derived the conditional mean of u given ε. Battese and Coelli (1988) derivethe best predictor of the technical efficiency of plot or farm j $TE_j = \exp(-u_j)$ as:

$$E\left[\exp\left(u_j/\varepsilon_j\right)\right] = \left[\frac{1 - F\left(\sigma_A + \gamma\varepsilon_i/\sigma_A\right)}{1 - F\left(\gamma\varepsilon_i/\sigma_A\right)}\right]\exp\left(\gamma\varepsilon_i + \sigma^2_A/2\right) \quad (4)$$

Where:

$$\sigma_A = \sqrt{\gamma(1-\gamma)}\sigma^2$$

The maximum likelihood estimates of the production function in Eq. 1 are automated in a computer programme, FRONTIER Version 4.1, written by Coelli (1996). FRONTIER provides estimates of β, $\sigma^2 = \sigma_u^2 + \sigma_v^2$, $\gamma = \sigma_u^2/\sigma^2$ and average technical efficiencies, as well as plot or farm level efficiencies. FRONTIER also provides the estimate for u when the symmetric error term follows a truncated normal distribution $u_j \sim N(\mu, \sigma_\mu^2)$. Factors influencing technical efficiency The literature suggests two methodological approaches for analysing the sources of technical efficiency based on stochastic production functions. The first approach is the two-stage estimation procedure in which first the stochastic production function is estimated from which efficiency scores are derived. In the second stage the derived efficiency scores are regressed on explanatory v least square methods or tobit regression. This approach has been criticized on grounds that the firm's knowledge of its level of technical inefficiency affects its input choices; hence inefficiency may be dependent on the explanatory variables. The second approach advocates a one-stage simultaneous estimation approach as in Battese and Coelli (1995) in which the inefficiency effects are expressed as an explicit function of a vector of farm-specific variables. The technical inefficiency effects are expressed as:

$$\mu_j = z\delta \quad (5)$$

Where for farm j, z is a vector of observable explanatory variables and δ is a vector of unknown parameters. Thus, the parameters of the frontier production function are simultaneously estimated with those of an inefficiency model in which the technical inefficiency effects are specified as a function of other variables. The one-stage simultaneous approach is also implemented in FRONTIER and in addition to the basic parameters the programme also provides coefficients for the technical inefficiency model.

Several factors including socioeconomic and demographic factors, plot-level characteristics, environmental factors and non-physical factors are likely to affect the efficiency of smallholder farmers. Parikh *et al.* (1995) using stochastic cost frontiers in Pakistani agriculture in a two-stage estimation procedure find that education, number of working animals, credit per acre and number of extension visits significantly increase cost efficiency while large land holding size and subsistence significantly decrease cost efficiency. Coelli and Battese (1996) in a single estimation approach of the technical inefficiency model for Indian farmers find evidence that the number of years of schooling, land size and age of farmers are positively related to technical inefficiency. Wang *et al.* (1996) use a shadow price profit frontier model to examine the productive efficiency of Chinese agriculture and find that a household's educational levels, family size and per capita net income are positively related to productive efficiency but off-farm employment is negatively related to efficiency. Taddese and Krishnarmoorthy (1997) report significant differences in technical efficiency across farm size groups with paddy farms on small and medium-sized holdings operating at a higher level of efficiency than large farms. They argue that because accessibility to institutional finance depends on asset position particularly land, small farms are forced to allocate their meagre resources more efficiently. Seyoum *et al.* (1998) use a one-stage model and find technical inefficiency to be a decreasing function of farmers ariables using ordinary education and hours of extension visits to farmers participating in the modern technology project. Education does not significantly affect the efficiency of farmers using traditional farming methods. Wadud and White (2000) apply a stochastic translog production frontier approach in Zimbabwe, both one-stage and two-stage technical inefficiency models. They find that inefficiency decreases with farm size and that farmers with good soils were significantly more technically efficient. Weir (1999) and Weir and Knight (2000) investigate the impact of education on technical efficiency in Ethiopia and conclude that household education positively influences the level of technical efficiency in cereal crop farms.

Owens *et al*. (2001) explore the impact of agricultural extension on farm production and determine that access to agricultural extension services raises the value of crop production by 15% in Zimbabwe. Ogundari and Ojo (2006) examined production efficiency of cassava farmer using farm level data with stochastic frontier production and cost function model to predict the farm level technical and economic efficiencies and found that cassava farms exhibit decreasing positive return-to-scale meaning that farmers were efficient in allocating there resources in Nigeria.

MATERIALS AND METHODS

A Cobb-Douglas stochastic production frontier approach is used to estimate the production function and the determinants of technical efficiency among smallholder maize farmers in Nigeria. Given the potential estimation biases of the two-step procedure for estimating technical efficiency scores and analysing their determinants, the one-stage procedure is adopted Battese and Coelli, 1995). Because of the small sample size of farmers with plots that are purely mono-cropped, the Cobb-Douglas production function is specified while controlling for soil fertility. Although this approach has its own limitations, it remains one of the popular production functions in production frontier studies. The following model is estimated on the basis of the Battese and Coelli (1995) procedure:

and

$$\text{In}\, y_j = \alpha + \sum_{i=1}^{m} \beta \quad \text{In}\, x_{ij} + \sum_{k=1}^{k} SQ_{kj} + v_j - u_j \tag{6}$$

$$u_j = \delta + \delta_j z_j + w_j \tag{7}$$

Where:

Plot j = y is the total quantity or value of maize produced

x = The quantity or value of input i used in the production process including labour, land, capital, quantity of fertilizers and quantity of seeds

SQ = A set of dummy variables for the quality of the soil

v_j = The two-sided error term

u_j = The one-sided error term (technical inefficiency effects)

Indicators: Output is measured as the maize produced on a plot in kilograms; land is measured as the total plot area cultivated in hectares and labour is estimated as person days worked. Fertilizer is the amount of fertilizer used on the plot in kilograms. The quantity of fertilizer used on some plots was zero, so it was used the approach in Sherlund *et al*. (2002) and equated the natural logarithm of zero to the logarithm of one-tenth of the smallest non-zero value in the sample (which turned out to be 1 kg of fertilizer used on the plot). Seed is the quantity of seed in kilograms, regardless of the type of maize seeds used on the plot. SQ is a three-category dummy variable representing quality of soils as identified by the smallholder farmers-poor, average and good soils. The inclusion of soil quality follows Sherlund *et al.* (2002), who find that environmental variables in the production function improve the estimated efficiencies. The one-sided error term (the technical inefficiency effect) u_j is shown in Eq. 7 in which z is a vector of socioeconomic characteristics of the farmer and the plot and w_j is the error term. In this study, the farmer is defined as the household member who controls production activities on each plot used for the production of maize only (mono cropped maize plots). The socioeconomic and plot level characteristics modelled in the inefficiency effect include education, application of fertilizer, use of hybrid seeds, membership in a farmers association and access to extension services.

Study area and the data: Osun state is located in the south western part of the country with a land area of 8,802 km^2 and a population of 2.2 million people. The state is agrarian and well suited for the production of permanent crop such as cocoa and oil palm and arable crops such as maize, yam and cassava because of favourable climatic conditions. The annual rainfall is between 1000 and 1500 mm with high daily temperature of about 30°C. The people are predominantly farmers with a relatively small holding ranging between 0.6-1.1 ha.

Data collection and sampling technique: The data used in this study were gathered through a smallholder farmer questionnaire administered to 200 households with information collected at household member level. The data collected include plot level output of maize and other food crops produced. The inputs used in the production process (land, capital, labour fertilizer and seeds) on each plot and the socioeconomic and plot-specific characteristics. The sample of smallholder farmers was drawn from four Local Governments Areas (LGAs) of the state using a combination of purposive and random sampling method. The LGAs include Oriade, Ilesa, Ede and Ife-East.

The choice of the study area was purposive because of the concentration of maize farmers in the area while the selection of the maize grower was random with 50 respondents each randomly selected from the list provided by extension officers of the state's Agricultural Development Project (ADP). In each of the selected households, the household head or a person with information about the farming activities of other household members was interviewed along with other individual members where necessary.

The 200 households interviewed had a total of 444 plots used for the production of various crops including 206 plots used for maize production. Of the total 206 plots on which maize was the main crop, only 48 plots from 37 house holds were used purly for maize production. Since the output and input data were only collected with respect to the main crop grown on the plot, data from 48 plots on which maize is monocropped are used in this study.

RESULTS AND DISCUSSION

Definitions of variables and descriptive statistics are shown in Table 1. The level of education among maize farmers is low as revealed by the mean years of schooling of 3.5 years. Most of the plots on which maize is grown are small with the mean plot size of 0.35 ha. This implies that most of the farmers interviewed were net food buyers. Fertilizers were applied to 52% of the plots while hybrid maize was the type of seed used on 48% of the plots. Only 6% of farmers come from households in which at least a member of the household has in an association and only 35% of farmers had access to extension services. The estimation of the Cobb-Douglas stochastic production function in Eq. 6 simultaneously with the technical inefficiency effects in Eq. 7 generates the results shown in Table 2.

The parameter $\gamma = \sigma_u^2/\sigma^2$ lies between 0 and 1 with a value equal to 0 implying that technical inefficiency is not present and the ordinary least membership square estimation would be an adequate representation and a value close or equal to 1 implying that the frontier model is appropriate (Piesse and Thirtle, 2000). The value of $\gamma = 0.5533$ is statistically significant at the 5% level which implies that more than half of the residual variation is due to the inefficiency effect. The one-sided generalized likelihood ratio tests of $\gamma = 0$ provided a statistic of 17.04 distributed as divided by $\varkappa^2$ with 7°C of freedom which is statistically significant at 1% level indicating that the average production function is not a suitable specification of maize production and technical efficiency effects are not random errors.

All the coefficients of the inputs in the production function are positive but only labour is statistically uses traditional technology that relies heavily on family labour.

The indicators of the quality of soils based on subjective judgements of the farmers are statistically significant at 5% level where soil quality was judged fair and at the 10% level where the soil quality was judged good. The estimated return to scale is 0.97, implying that maize is produced close to constant returns to scale on the sample plots. The mean technical efficiency level among smallholder maize farmers is 46.23 with a standard deviation of 23.3% and a range from 8.12-93.95%. The mean levels of efficiency are low but comparable to those

Table 1: Definition of variables and descriptive statistics

Variables	Description	Mean±SD
Production function		
ln maize	Natural log of the quantity of maize cultivated (kilograms)	4.385±1.131
ln land	Natural log of the plot size under maize cultivation (hectares)	1.041±0.895
ln capital	Natural log of the value of capital at current cost used on the plot (Malawi Kwacha)	5.820±0.819
ln labour	Natural log of family and hired labour used (man-days)	3.418±1.216
ln fertilizer	Natural log of the quantity of fertilizer (kilograms)	0.313±2.698
ln seed	Natural log of the quantity of seeds (kilograms)	1.835±1.005
SQ-fair	Dummy: 1 if soil quality was judged average by farmer	0.229±0.425
SQ-good	Dummy: 1 if soil quality was judged good by farmer	0.271±0.449
Inefficiency model education	Number of years of schooling for the farmer	3.458±3.408
Fertilizer	Dummy: 1 if the farmer used fertilizer on the plot	0.521±0.505
Hybrid	Dummy: 1 if the main type of maize on the plot is hybrid	0.479±0.505
Association	Dummy: 1 if any of the members of the household belongs to a club or association	0.063±0.245
Extension	Dummy: 1 if the farmer had access to extension services-farmers was at least visited by extension workers.	0.354±0.483

Table 2: Maximum likelihood estimation of the production frontier with inefficiencymodel (dependent variable: ln maize)

Variables	Coefficient	t-ratio
Production function		
Constant	2.4858**	2.5868
ln land	0.1764	1.0667
ln capital	0.2584	1.5862
ln labour	0.2413*	1.7031
ln fertilizer	0.1143	1.1425
ln seed	0.1800	0.1090
SQ-fair	0.6923**	2.4416
SQ-good	0.7407*	1.9617
$\sigma^2 = \sigma^2_u + \sigma^2_v$	0.6173***	3.1169
$\gamma = \sigma^2_u / \sigma^2$	0.5533**	2.3617
Log likelihood	-50.8740	-
Number of plots	48.0000	-
Inefficiency model		
Constant	1.1045*	1.9617
Education	0.0337	0.5631
Fertilizer	0.0942	0.1473
Hybrid	-1.2259***	-3.5372
Club	-5.3472***	-3.5160
Extension	0.6637	1.6001

***Statistically significant at 1% level; **Statistically significant at 5% level; *Statistically significant at 10% level

from other African countries. For example, Chirwa (1998) find the same figure for Malawi. Seyoum *et al*. (1998) find the mean technical efficiency of maize producers in Ethiopia to be 79%. Weir (1999) and Weir and Knight (2000) find mean efficiency levels of about 55% among Ethiopian cereal crop producers while Mochebelele and Winter-Nelson (2000) find average technical efficiencies of between 64 and 76% in Lesotho.

The technical inefficiency model shows that two of the five variables are statistically significant at the 1% level. The coefficient of education is positive but statistically insignificant, suggesting that better educated farmers produce maize inefficiently which is contrary to expectations. One explanation is that maize is mainly produced for subsistence using traditional methods and the education of farmers does not play a role in the optimal combination of inputs. Similarly, the dummy representing adoption of fertilizers is statistically insignificant given that almost half of the smallholder farmers in the sample adopted this technology. It is quite possible that although some farmers did use fertilizer technology given the low level of education among most farmers and the small land holdings, they may have applied it inappropriately. Dzimadzi *et al*. (2001) in the case of a targeted input safety net programme find that problems of literacy and numeracy led farmers to use the inputs inappropriately. In some cases, inputs were used on larger areas than the technical specifications contained in the leaflets and in other cases the instructions conflicted with the traditional farming systems. Sibale *et al*. (2001) find that only 50% of respondents followed the targeted inputs programme instructions for planting maize. The coefficient of the dummy representing use of hybrid seeds is statistically significant at the 1% level. Plots with hybrid maize seeds are more efficient than plots using local seeds. Local maize seeds are usually preferred by most smallholder farmers because of the quality of maize flour produced through the traditional system, fewer demands on fertilizers and ease in storage, it is not susceptible to pests and it can be recycled as seed (Smale, 1995).

As a result, despite major investments in research and development to produce high yielding maize seeds, most farmers in Nigeria still prefer local maize to improved maize.

The coefficient of the dummy variable for membership in a farmer association is statistically significant at the 1% level. Membership of association is part of social capital. Binam *et al.* (2004) also use club membership to capture the role of social capital in providing incentives for efficient farm production and find similar results. The sharing of information on crop husbandry information at association level tends to filter to other members of the households that are not members or through demonstration effects of farming practices association members plots. Thus membership of association has some external effects on family members who are not members of the farming association.

The relatively low levels of technical efficiency among smallholder maize farmers in south-western Nigeria point to the need to pursue policies that enhance the organization of farming systems in the country. One of the main constraints facing agriculture in Nigeria is the small size of the land holdings which are becoming smaller and smaller through subdivision to family members. Given that maize is one of the main staple food in Nigeria, food production efficiency and food security can be enhanced through policies that increase the utilization of the existing small holdings by promoting adoption of high yielding maize varieties and by promoting networks among farmers. Over the years, smallholder agriculture was largely organized around farmers groups for effective delivery of extension services and agricultural credit. The farmer group/association system is almost collapsing.

Following the collapse of the agricultural credit scheme that worked through the group system and only a few farmers today belong to farmers group or association. The significance of association membership found in this study points to the need for the revival of the farmer association system or the development of farming cooperatives in Nigeria.

CONCLUSION

The results are based on a small sample of smallholder farmers in four LGAs South-Western Nigeria and may not necessarily be representative of the entire smallholder sector with its varying land holding sizes in different ecological zones. Furthermore, it was not possible to control for differences in the family life cycle and the natural abilities of farmers through fixed effects modelling due to the limited number of plots cultivated by the farmers or households.

RECOMMENDATIONS

Two main policy issues emerge from the results of this study. First, there is need to promote adoption of hybrid seeds among smallholder maize farmers. The government policy of subsidizing hybrid maize seeds and fertilizers is consistent with the findings of this study. Second, there is need to enhance social capital in smallholder farming through the revival of farmers association or through the creation of agricultural cooperatives.

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