Journal of Agriculture and Food Research 14 (2023) 100707

Contents lists available at ScienceDirect

Journal of Agriculture and Food Research

journal homepage: www.sciencedirect.com/journal/journal-of-agriculture-and-food-research

The role of development interventions in enhancing technical efficiency of sunflower producers

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ARTICLE INFO

Keywords:
Policy analysis
Efficiency
Production techniques

ABSTRACT

A key policy concern in African agriculture is low productivity even when new technologies are generated, disseminated and adopted among farmers. This study used a cross-sectional dataset from a sample of 202 sunflower farmers drawn from northern Uganda to determine technical efficiency and assess the influence of farmer management capabilities, development intervention and socio-economic factors on technical efficiency. Results reveal that technical inefficiency among sunflower farmers account for 81% of farm-level output. Further, farmer management capabilities ($p<0.01$), participation in development interventions ($p<0.01$) and reliance on certified seeds ($p<0.01$) significantly reduce farmer inefficiency and thus, improve technical efficiency. The study highlights that focusing on farmer management capabilities to improve farm efficiency is more cost-saving for realizing economic gains in sunflower production rather than introducing new technologies. We recommend a policy focus on using approaches such as farmer field schools that ensures farmer advisory services at all critical stages of crop growth.

1. Introduction

One tenet of agricultural productivity in smallholder farming contexts of Africa is efficient and effective use of farm resources ([1]; Food and Agriculture Organization [2]). This appears to inform the focus of policy interventions which are generally biased towards generation and dissemination of technologies [3,4]. Such technologies range from improved crop varieties, commonly marketed as certified seeds, livestock breeds, fertilizers and farm equipment. However, current policy interventions have barely translated into better farm yields. Instead, agricultural productivity stands at only 40% of its expected potential, and it has continued to decline over the years [5]. A similar trend is evident among Ugandan sunflower farmers who operate on small farmland sizes averaging less than 2 acres [6]. At consumption level, the yield gap creates scarcity of cooking oil and thus, the negative impact on nutrition and health of individuals [7–9]. It has also created a dependence on imported cooking oil so as to meet an estimated demand gap of 60% [10].

Sunflower, as an oil crop, features prominently on the development agenda of the government of Uganda (Ministry of Agriculture Animal industry and Fisheries [11]. It is one of the crops prioritized for research and development with the main foci of improving household incomes and earning foreign exchange ([11]; Vegetable Oil Development Project [12]. Arising out of public-funded agricultural research, a number of varieties have been released namely: *Agsun 8251*, *Hysun*, *NK ferti*, among others [12]. Further, private-public initiatives have been established not only for enabling ease of access to researched technologies among intended beneficiaries but also facilitating market linkages for sunflower growers. In effect, contract farming involving private sector actors and networks of smallholder sunflower growers has increased in northern Uganda. Within the existing frameworks for contract farming, a common practice is availing certified seeds of improved varieties to sunflower growers [13]. However, the increase in access to certified seeds at the grassroots has not led to notable changes in productivity suggesting that farmers might be technically inefficient in applying the technologies at farm-level.

Technical efficiency (TE) is concerned with producing more output for a maintained level of resources or attaining a maintained level of output for less resources. The basis for analyzing technical efficiency is to minimize resource wastage while guaranteeing more output [14]. In the context of sunflower production, TE may entail effective use of: i) factors of production (farmland and labor), ii) agricultural inputs

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https://doi.org/10.1016/j.jafr.2023.100707
Received 16 November 2022; Received in revised form 30 June 2023; Accepted 1 July 2023
Available online 10 July 2023

(fertilizers, pesticides, seeds and capital equipment); and iii) farmer skills [15,16]. This means that TE relates to individual capabilities of farmers in converting inputs into outputs and such capabilities may be improved through training. For instance, educational programs can enhance farmer knowledge and skills in optimizing seeding rates, fertilizer application and minimization of postharvest losses. Overall, it has been argued that if the productive potential of existing technologies is not yet fully utilized, it might be worth focusing attention on improving farmer production techniques [17,18].

Previous research on TE has tended to be modeled via either the Cobb-Douglas (CD) production function or translog cost function and the constant elasticity of substitution [CES] production function [19,20]. However, the CD production function has remained popular because it adequately represents the farmer production process [21–23] and thus, its preference in the current study. Moreover, the application of the stochastic frontier analysis on the CD production function allows concurrent estimation of technical efficiency along with the inherent factors that influence the observed inefficiency [a common characteristic of African agriculture] [24–26]. That aside, a rich body of research literature on African agriculture and TE suggests that improving farmer management capabilities in executing production techniques is important for attaining production efficiency. However, the actual estimation of the effects of these farmer management capabilities, and most particularly in contexts of farmer participation in development interventions is still lacking. As such, a knowledge gap exists on how farmer management capabilities combine with development intervention and socio-economic factors to affect technical efficiency. Therefore, the purpose of this study was to: i) assess the linkage of development interventions with farm-level technical efficiency; and ii) analyze the role of farmer management capabilities in enhancing technical efficiency among sunflower growers. Results in this study are applicable to a wide spectrum of African agriculture where technology dissemination among farmers is only yielding sub-optimal productivity, just like the case of vegetable-oil subsector in Uganda.

1.1. Theoretical perspectives on production efficiency

The prevalence of low yields among sunflower growers, amidst widespread contract farming and dissemination of improved varieties, makes technical efficiency (TE) approach appropriate for analysis in this study. The TE theory was advanced by Farrell [27] who illustrated that the production function has a limit or boundary showing a range of possible observed output levels for a given bundle of inputs based on the management capabilities of the decision-making unit (DMU). For instance, the DMU such as the sunflower farmer may combine farm resources namely; labour, capital (e.g., seeds) and land to produce output [25].

Accordingly, TE has been defined as the ability of the DMU to minimize input use in the production of an output vector or the ability to obtain maximum output from an input vector [28]. The assumption underlying the TE concept is that farmers operate on the outer boundary of the production function commonly referred to as the efficient frontier. In practice, however, most farmers produce output way below the production frontier [26,29]. As such, the task of policy analysts (or researchers) is to identify and quantify the extent of deviation of farmer production using current technologies from the level of efficient frontier.

Extant literature shows that existing technical inefficiencies in an industry, firms or among farmers can be reduced through three main ways. First, by introducing improved production techniques, which implies a change in factor proportions through factor substitution under a given technology, and thus bringing a positive change along a given production function. Second, improvement in production technology, which can bring an upward shift in the production function, in a way suggesting that the same amount of resources produce more output, or the same amount of output is derived from smaller quantities of resources than before [30,31]. Third, a simultaneous improvement in both production techniques and technology [32]. From a policy analysis perspective, pursuing the intervention strategy of improving production techniques is a more cost-effective option if farmers have not exhausted TE at the current technology level rather than going for an expensive and time-consuming option of technology generation through research.

Two econometricians, namely; Aigner et al. [33] and Meeusen &Van Den Broeck [34] independently introduced the stochastic frontier analysis of production function (SPF). The SPF assumes that maximum output may not be obtained from a given input or a set of inputs because of the inefficiency effects. The SPF model has the advantage of allowing simultaneous estimation of individual TE of respective farmer(s) as well as the determinants of technical inefficiency. The assumption of this production function is that a given farm under analysis uses n inputs: X_1, $X_1, \ldots X_n$ to produce output Y. For such a farm, its efficient transformation of inputs into output is characterized by the production function, $f(X)$. Econometrically, this can be expressed as shown in equation (1):

$$Y_i = f(Xa_i; \beta) + \varepsilon_i \tag{1}$$

Where,

Y_i is the quantity of agricultural output,
Xa_i is a vector of input quantities, and
β is a vector of parameters
ε_i is an error term defined as in equation (2):

$$\varepsilon_i = V_i - U_i \tag{2}$$

$i = i^{th}$ farmer in the sample

V_i is a symmetric component that accounts for pure random factors on production, which are outside the farmers' control such as weather, disease, topography and U_i is a one-sided and non-negative component, which captures the effects of inefficiency and hence measures the shortfall in output Y_i from its maximum value given by the stochastic production frontier. From equation (1), the model can further be expressed as in equation (3):

$$Y_i = \exp(Xa_i; \beta) + V_i - U_i \tag{3}$$

Accordingly, the actual technical efficiency (which tends to be not the outer boundary of frontier efficiency) of production of the i^{th} farmer in the sample can be expressed following equation (4).

$$Y_i = \exp(-U_i) \tag{4}$$

Further, V and U are assumed to be two-sided, where V is the normally distributed random error with zero mean and variance ($V_i \sim N(0, \sigma_V{}^2)$ while U is the one-sided efficiency component of the error term with a half normal distribution ($U_i \sim /N(0, \sigma_U{}^2)$.

The overall model variance is thus expressed as shown in equation (5):

$$\sigma^2 = \sigma_V{}^2 + \sigma_U{}^2 \tag{5}$$

The measures of total variation of output from the efficient frontier, which can be attributed to technical efficiency, are lambda [λ] and gamma [γ] [35]. Also, Jondrow et al. [36] derived the variability measures as shown in equations (6) and (7):

$$\lambda = \frac{\sigma_U}{\sigma_V} \tag{6}$$

$$\gamma = \frac{\sigma_U{}^2}{\sigma_V{}^2 + \sigma_U{}^2} \tag{7}$$

In practice, the SFP is estimated using the method of maximum likelihood. Maximum Likelihood Estimation (MLE) method allows for simultaneous estimation of the TE as expressed in equation (3) together with the factors that affect technical efficiency (or sources of inefficiency) of the i^{th} farmer in the sample. Literature shows that among the factors that might affect TE are the socio-economic characteristics of the farmer, for instance age and education. Further, existing studies have tended to suggest that management practices are important in the TE of the farmer in question. However, most of previous research has always fallen short of empirical testing of the management capabilities to show how they influence TE which this study operationalized. This study hypothesizes that sunflower farmers experience less than optimal TE and that management capabilities combine with development interventions and socio-economic factors to positively influence TE.

2. Materials and method

2.1. Study site and population

A cross-section study was carried out during period of December 2017 and January 2018 among sunflower farmers of Oyam District, Uganda. This District is located in northern Uganda on 02 14 N, 32 23E coordinates. Oyam District has a bimodal-type rainfall pattern of about 1,200–1,600 mm per annum, which is sufficient for sunflower production. The first season peaks in April–May while the second season peaks during the months of August–October. These rainfall conditions are important for vigorous growth of sunflower. The general population in the study area, is dominated by smallholder farmers [37]. These farmers generally practice a mixed cropping system involving a collection food crops (e.g., sweet potatoes, maize, cassava) and sunflower as a cash crop. While the number of sunflower farmers in the area has been rising, depicting the importance of this crop to farmers, yields at farmsteads have barely matched the productive expectations of researchers [13].

2.2. Data sources

Primary data were collected from a sample of smallholder sunflower farmers drawn from the study area. The study adopted proportional sampling approach to select 202 respondents who included both participants and non-participants of the development interventions in vegetable oil sub sector. Sunflower growers with linkage to the public-private partnership, recruited in producer groups and contracted as out growers by private firms constituted the category of participants. Lists of farmers from eight (8) groups constituted the sampling frame for the participants category from which 97 respondents were selected. Despite the intervention, a bigger proportion of sunflower farmers are still not enrolled into contract farming with private firms. Such non-participant farmers tend to believe that they can get better prices outside contract farming. Accordingly, this study selected up to 105 non-participants for inclusion into the final sample. Procedurally, a list of non-participant farmers was generated with the help of local leaders from the 12 villages of operation of contracted farmers groups. This list formed the sampling frame for the non-participant sunflower farmers. Subsequently, systematic sampling was used to select non-participant farmers for inclusion in final sample by picking one farmer on list after skipping two.

A pretested questionnaire was used to collect data and it had close-ended questions which included the Likert scale and multiple-choice questions from which respondents made choices describing their situations. The questionnaire also had open-ended questions which allowed respondents freedom of expression in describing own farming situations. The main sections of this questionnaire were as described below. First, the socio-economic factors (Table 1) comprised of age of household head (years), education level of household head (years), farming experience (years), farm-size (acres), non-farm employment (if yes = 1; otherwise = 0). It also captured information on the household structure including: number of household members, dependents and working members. Other captured information included: participation in development interventions i.e. the vegetable oil development project (if participant = 1; otherwise = 0), reliance on certified seeds (if yes = 1; otherwise = 0), credit access (if yes = 1; otherwise = 0) and membership to social network (if yes = 1; otherwise = 0) as well as distance to produce market

Table 1
Characteristics of the sampled sunflower farmers.

Characteristic(s)	Mean (n = 201)	Minimum	Maximum
Household size (number)	6.4	1.0	12.0
Educational level (years in school)	4.4	0.0	13.0
Age (years)	40.3	19.0	17.0
Farming experience(years)	17.3	1.0	50.0
Sunflower production experience (years)	4.1	1.0	17.0
Access to produce market (km)	5.4	1.0	30.0
Farm size (acres)	5.4	1.0	40.0
Land under sunflower (acres)	2.8	0.3	27.0
Manual labor (man-days)	39.2	11.4	76.5
Seed rate (kg/acre)	1.6	0.5	4.0
Sunflower output (kg/acre)	361.0	43.0	980.0
	Description (s)	**Frequency**	**Percentage**
Sex	Female	31	15.4
	Male	170	84.6
Participation in development interventions	Non-participants	105	52.2
	Participants	96	47.8
Certified seeds	Recycled seed	18	9.0
	Certified seed	183	91.0
Credit access	Access	72	35.8
	Non access	129	64.2
Membership to social network	Membership	120	59.7
	Non membership	81	40.3
Access to extension	Access	49	24.4
	Non access	152	75.6
Use of draught animals ((if yes = 1, otherwise = 0)	Yes	109	53.9
	No	93	46.1

(km). The second section captured information on sunflower production as follows: sunflower output (kg/acre), labor (man-days), seed rate (kg/acre), land under sunflower cultivation (acre), use of draught labor (if yes = 1, otherwise = 0). The third section captured farmer management capabilities operationalized using the management capabilities framework of Rougoor et al. [38] & Mäkinen [30]. This framework includes farm planning, strategic thinking, crop establishment management and crop growth management. In this section, the items were measured on a standardized 5-point Likert scale ranging from 1 = Not at all to 5 = Always. A sample item reads as follows: In our household, we prepare farming business plans for sunflower production.

2.3. Analytical methods

Consider a sunflower farmer whose objective function is maximizing output (Y) using production inputs of capital [seeds] (K), land (A) and labor (L). The production technology would then be defined by the Cobb-Douglas production function as shown in equation (8):

$$Y = f(AKL) \tag{8}$$

Since in practice, farmers rarely produce along the production frontier, the above functional form of the production function can be modified to reflect the inefficiency. Accordingly, this study assumes that the sunflower farmer experiences inefficiencies that reduce the output level attained. Therefore, the sunflower farmer's production function can empirically be expressed as a stochastic Cobb-Douglas production frontier as shown in equation (9):

$$\ln Y_i = \beta_0 + \beta_j \ln[X_i] + V_i - U_i \tag{9}$$

Where; Y_i represents the sunflower output standardized for one acre for the i^{th} sunflower farmer. $[X_i]$ is a vector of production inputs namely quantity of sunflower seeds (K) in kg used in the production process, land under sunflower production (A) in acres and the amount of labor

(L) in man-days employed in sunflower for the i^{th} sampled farmer and the dummy variable for use of draught labor such as oxen (D, if yes = 1, otherwise = 0). β_0 is the constant while β_j are the parameters to be estimated on the inputs where $j = 1, 2 \ldots n$, and $n = 4$. ln represents linearization in natural logarithms so as to normalize variables used in the equation (9). V and U are as explained in equation (3).

For the sources of technical inefficiency among sunflower farmers that are simultaneously determined together with TE the following regression model (equation (10)) was run:

$$U_i = \delta_0 + \delta_k[X_i] + \varepsilon_i \tag{10}$$

Where U_i is the technical inefficiency estimate for the i^{th} farmer in the sample. $[X_i]$ is the vector of factors affecting technical efficiency and these include: participation in the development interventions of the vegetable-oil subsector (if yes = 1; otherwise = 0); reliance on certified seeds for sunflower production (if yes = 1; otherwise = 0). Other factors included farmer management capabilities, computed as an index of strategic thinking of the farmer, farm planning ability, crop establishment management and crop growth management. In addition, socio-economic characteristics of the farmer were included in the vector of sources of inefficiencies which included farm size (acres), age of the farmer (years), household size, distance to the produce market (km), and education level of the farmer (years of schooling). Others were membership with a social network (if yes = 1; otherwise = 0) and access to credit services (if yes = 1; otherwise = 0). δ_0 is the constant of the inefficiency model and δ_k are the parameter estimates of the sources of inefficiency where $k = 1, 2\ldots n$ and $n = 10$. ε_i is the error term.

Prior to technical efficiency analysis, all variables specified for empirical estimation of the stochastic production frontier were tested for multicollinearity and heteroscedasticity. For multicollinearity, correlation matrix was used to investigate the dependence between multiple variables at the same time. The decision rule is that correlates should not exceed the value 0.7 in order to rule out the possibility of multicollinearity affecting sound interpretation of the statistical findings. In this study, one of the two variables whose pairwise correlation coefficients were above 0.7 was excluded from the final empirical model as explained in Dormann et al. [39]. White's test for homoskedasticity was used to test for heteroskedasticity. The model had a chi-square value of 181.79 hence failure to reject the null hypothesis that the variances were constant at 1% level of significance.

Apriori sign expectations of the parameters estimated in equations (9) and (10) are as presented in Table 2 below:

Table 2
Apriori sign expectations of variables used in the study.

Variable	Description	Apriori sign	Supporting Literature
Manual Labor	Total manual labor used in sunflower production in man-days/acre	+	Olujenyo [40]; Sibiko et al. [41].
Draught labor	Use of ox-traction in sunflower production	+	Reardon et al. [42].
Sunflower Seeds	Total quantity of seeds used in sunflower production in Kg/acre	+	Sibiko et al. [41] & Mustapha & Salihu [43].
Land for Sunflower	Total area of land under sunflower in acres	+	Sibiko et al. [41]; Kalule [31].
Inefficiency model			
Intervention participation	Participation in development intervention	-	Seyoum et al. [44]; Ullah et al. [45].
Reliance on certified seeds	Type of seed planted by sunflower farmers	-	Okello et al. [46]; Harun & Ilyas A [47].
Farmer management capabilities	Farmers management capabilities scores	-	Siebers et al. [48]; Makinen [30].
Credit access	Access to credit services	−	[49]; Nyagaka [50].
Household size	Number of people in the household	−	Mbanasur & Kalu [51]; Ataboh et al. [52].
Age of household head	Number of years of the sunflower farmer in years	+	Simonyan et al. [53]; Yami et al. [54].
Education level of household head	Highest educational level of the household head in years	−	Nyagaka [50]; Mugonola et al. [55].
Farm size	Size of the farmland in acres	+/-	Sibiko et al. [41]; Hyuha et al. [56]
Social network membership	Membership to social network group	−	Binam et al. [57, 58]
Distance to the produce market	Proximity to the nearest produce market in Km	−	Mugonola [55]; Sibiko et al. [41]

3. Results and discussion

Table 3 presents the results of the maximum likelihood estimation (MLE) of the stochastic Cobb-Douglas production function. The results show that all the coefficients of production factors namely manual labor (β = 0.14; P<0.05), seeds (β = 0.14; P<0.01) and land under sunflower (β = 0.78; P<0.01) significantly affect sunflower output. The only variable not significant is the use of draught labour.

These production factors are also positively signed and therefore in conformity with theoretical prediction. It is only draught labor that is not significant but still positively signed. This means that the specified production factors are source of output among sunflower farmers. Literally, the findings mean that increasing manual labor and seeds by 10% would each lead to a rise in sunflower output by 1.4% *ceteris paribus*. While for land, the same percentage increase improves output by 7.8% *ceteris paribus*. The value of elasticity of 1.07 suggests increasing returns to scale. This means that doubling the input levels in sunflower production would lead to more than doubling the output level. As such, the finding implies that the productive potential of the current technology in use is not yet fully utilized among the sunflower farmers.

On technical efficiency, the log likelihood function (LR = 8.40; χ^2 = 1612.72; P< 0.05) is highly significant implying that the empirical

Table 3
Maximum Likelihood Estimation of the stochastic frontier of production function.

Variable	Co-efficient (β)	Standard Error	Z-value
Manual Labor (man-days)	0.14	0.06	2.27**
Use of Draught labor (yes = 1)	0.01	0.02	0.51
Sunflower Seeds (kg)	0.14	0.05	2.58***
Land for Sunflower (acres)	0.78	0.07	11.84***
Elasticity	1.07		
Inefficiency effects			
Intervention participation (yes = 1)	−2.17	0.61	−3.56***
Reliance on certified seeds (yes = 1)	−1.08	0.51	−2.12**
Farmer management capabilities (index)	−1.46	0.54	−2.71***
Credit access (yes = 1)	−0.13	0.38	−0.35
Household size (number of members)	−0.05	0.08	−0.62
Age of household head (years)	0.01	0.02	0.67
Education level of household head (years)	−0.19	0.08	−2.27**
Social network membership (yes = 1)	−1.69	0.41	−4.07***
Distance to the produce market (km)	0.01	0.02	0.41
Size of farmland (acres)	0.01	0.04	0.37
Variance parameters			
Sigma square (σ^2)	0.14**	0.02	
Lambda (λ)	2.03*	0.06	
Gamma (γ)	0.81**	0.02	
Log likelihood Ratio (LR) test	8.40		
Wald χ^2 (4)	1612.72**		

***p < 0.01, **p < 0.05, *p < 0.1.

model specifying the factors that influence technical efficiency adequately fitted the Cobb-Douglas functional form. Therefore, the hypothesis that farm management capabilities combine with development interventions and socio-economic factors to positively influence technical efficiency among sunflower farmers could not be rejected. Lambda ($\lambda = 2.03$; $P < 0.1$) is also significant meaning that the distributional assumptions for the estimated technical inefficiency among sunflower farmers are met in this study. Similarly, gamma ($\gamma = 0.81$; $P < 0.05$) is significant and further, affirms the existence of technical inefficiency among sunflower farmers. This finding means that 81% of the total variation in output of sunflower is attributable to technical inefficiency rather than factors beyond the control of the farmers. Lastly, sigma-square ($\sigma^2 = 0.14$; $P < 0.05$) is significant confirming that the data used in this study fitted the specified assumptions of the distribution of the double-sided error term comprising of the random error and the technical inefficiency.

Results on factors influencing technical efficiency (Table 3) show that both participation in development interventions ($\beta = -2.17$; $P < 0.01$) and reliance on certified seeds ($\beta = -1.08$; $P < 0.05$) significantly reduce inefficiency and thus, improve technical efficiency. These findings are in agreement with the theoretical prediction. Incidentally, interventions in the agricultural sector have tended to emphasize use of certified seeds rather than home saved seeds which are less productive. This could be the reason why certified seeds improve technical efficiency. The current study agrees with results reported earlier on the role of development interventions in improving technical efficiency. For instance, it has been reported that participant farmers in extension services experience better technical efficiency than their non-participants counterparts[44,56].

Results further reveal that farmer management capabilities ($\beta = -1.46$; $P < 0.01$) have a significant reducing effect on technical inefficiency. This finding is as hypothesized in the current study. This piece of empirical evidence underscores the importance of sound farm management as argued in previous research [59]. It can thus be argued that focusing on the farm management activities offers a good avenue for pursuing increases in technical efficiency. Other factors that significantly reduce technical inefficiency include education level of household head ($\beta = -0.19$; $P < 0.05$) and membership with a social network ($\beta = -1.69$; $P < 0.01$). The findings on education and membership with social network agree with earlier research [55,57] respectively. Extant literature explains the importance of social networking in terms of affording farmers knowledge for farming through social learning and so the opportunity of reducing technical inefficiency [58]. Existing literature on education also explains that educated farmers tend have better access to agricultural information and have a higher ability to adopt and use improved inputs more optimally and efficiently [50]. For the variables of credit access, household size, age, distance to the produce market and size of farmland, no significant effects were detected and therefore treated as inconclusive.

Results of comparison of participant and non-participant farmers of development interventions for technical efficiency levels are presented in Table 4. These results show that in the overall sample, efficiency levels ranged from 21% to 95%. Further, the results reveal that although there are inefficiencies among participant farmers of development interventions, they exhibit better technical efficiency levels compared to their counterparts.

Over 64% of participant farmers have efficiency levels greater than 80%. Contrastingly, for non-participant farmers, only 11% of this group have efficiency levels in the region above 80%. The efficiency of an average farmer among participant farmers of development interventions stands at 81% while it is 62% for non-participant farmers. The finding on the gaps in technical efficiency supports earlier research which has reported African smallholder farmers experience high inefficiencies in their production [43].

Since inefficiencies persist among sunflower farmers even after participation in development interventions that associated with reliance

Table 4
Technical efficiency differentials for participation in development interventions.

Efficiency Score	Percent (%) distribution of sampled farmers		
	Pooled sample (n = 202)	Participation in development interventions	
		Non Participants (n = 105)	Participants (n = 97)
0 - 0.50	9.9	18.1	1.0
0.51 - 0.60	10.4	18.1	0.0
0.61 - 0.70	22.8	28.6	8.2
0.71 - 0.80	23.3	24.8	26.8
0.81 - 0.90	31.2	9.5	58.8
0.91 - 1.00	2.4	1.0	5.2
Other statistics on technical efficiency			
Mean efficiency	0.71	0.62	0.81
Minimum efficiency	0.21	0.21	0.41
Maximum efficiency	0.95	0.92	0.95

on improved technologies such as certified seeds, it means that alternative approaches of farmer services might be useful in pursuing farm productivity. It thus suffices to suggest that it is cost-saving for the development interventions to pursue output by improving management capabilities of farmers rather than introducing new technologies. One interesting finding is that, if the least-efficient farmer and average-efficient farmer for intervention participants upgraded their management capabilities to the quality level of the most-efficient farmer, the economic (efficiency) outcomes improve by 57% i.e., $\left[1-\left(\frac{0.41}{0.95}\right)\right]$ and 14% i.e., $\left[1-\left(\frac{0.81}{0.95}\right)\right]$, respectively. Relatedly in the non-participants' category, if the least-efficient and average-efficient farmers applied the quality of management capabilities of the most-efficient farmer in the sample, the economic outcomes rise by 78% i.e., $\left[1-\left(\frac{0.21}{0.95}\right)\right]$ and 35% i.e., $\left[1-\left(\frac{0.62}{0.95}\right)\right]$, respectively. It can further be argued that inefficiencies still persist in sunflower production despite improved access to better technologies, including the emphasis on certified seeds in development interventions. It particularly affirms the finding in this study that the productive potential of the current technology employed by sunflower farmers has not been fully exploited.

4. Conclusion and recommendations

Sunflower farmers have persistently experienced low yields despite increased access to superior technologies/crop varieties and certified seeds. This particularly suggests that the source of low productivity might not necessarily be lack of high-yielding technologies but rather inefficient application of these technologies at farm-level. In this study, results reveal existence of inefficiencies across all sunflower growers but such inefficiencies are less pronounced among participants than non-participants of development interventions. Further, results also show that the major factors that improve technical efficiency are participation of sunflower farmers in development interventions of vegetable-oil subsector, reliance on certified seeds, quality of farmer management capabilities, social networking and education level of household head. The study concludes that the productive potential of the current technology in use is still not yet fully utilized due to the existence of inefficiencies. It also concludes that good quality farmer management capabilities notably, farm planning, crop establishment management (e.g., seeding rate) and crop growth husbandry offer a cheap option of increasing output levels through extracting the locked-in efficiencies rather than shifting to generation and introduction of new technologies.

On theoretical development, the study deepens the concept of technical efficiency by integrating farmer management capabilities into the stochastic production frontier analysis which previous research, without empirical testing, has tended to suggest are vital in pursuing farm efficiency. It particularly demonstrates that farmer management capabilities combine with development interventions and socio-economic factors to improve farm-level technical efficiency. For practice, the study yields results of relevance to farmers and extension services in that focusing on production techniques brings better efficiency in utilization of farm resources i.e., seeds (in this case, certified seeds), land and labour, and hence, an opportunity of enhancing productivity and overall sunflower production. For policy action, this study demonstrates that it is cost-saving to pursue more economic gains by improving farmer production techniques at the current technology level rather than conducting research to generate new technologies. This is because the productive potential of the current technology has not been fully exhausted by the quality of farmer management capabilities. We call for cost-saving policy interventions, oriented around improving farmer production techniques, in pursuit of better technical efficiency and farm-level productivity. In this case, farmer educational programs need to pay more attention to improving the quality of application of production techniques such as the seeding rate, row cropping and overall crop husbandry practices. One limitation of the study is that the role of pre- and post-harvest operations were not tested in this study which are now recommended for further research.

Credit statement for author contribution

1. Toma M. Zozimo – conceptualized the study, undertook data collection, analysis, reporting and drafting the manuscript.
2. Geofrey Kawube – participated in research supervision and writing and editing the manuscript.
3. Stephen W. Kalule - participated in conceptualization, data analysis, research supervision and drafting the manuscript.

Declaration of competing interest

We the authors have no conflict of interest to disclose.

Data availability

Data will be made available on request.

Acknowledgement

The authors are grateful to the Regional Universities Forum for Capacity Building in Agriculture (RUFORUM) for funding the study under Grant number: RU 2016 NG 38.

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