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The Level and Determinats of Technical Efficiency in Fodder Production in Homa Bay County, Kenya

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Abstract

Fodder production is important for dairy producers in Kenya as it plays a major role in the quality and quantity of milk produced. It contributes to improved income through forage sales, milk sales and livestock sales. There has been an increasing demand for fodder both locally and in neighboring countries. This has led to an increase in the production of fodder in the country. Despite the growing demand of fodder in Kenya, the current production does not meet the demand. In response, efforts have been initiated by different programs with the help of the International Livestock Research Institute (ILRI), towards promoting fodder production with a view to increasing milk production. This paper analyzed the level of technical efficiency and its determinants in fodder production. Primary data was collected in Rachuonyo East and South sub-counties using structured questionnaires on a sample size of about 300 farmers. Stochastic Frontier model and Tobit model were used for analysis. Results of stochastic frontier analysis indicated that land size, quantity of planting materials, labour for planting, and labor for weeding influenced the level of technical efficiency. Tobit's results indicated that herd size, group membership, access to credit, household size and access to training affected the level of technical efficiency of farmers. The study recommended the need for farmers to increase land allocation for fodder, increase planting materials and the number of man days during planting and weeding to increase fodder output.

Subject Areas

Economics

Keywords

Fodder, Production Technology, Technical Efficiency

1. Introduction

In smallholder farms in Kenya, the cost of dairy feeding accounts for between 60 and 80 percent of overall production expenses, and efficient feeding has the potential to increase farmers' profit margins significantly [1]. The production of fodder is progressively gaining popularity as a source of both feed for livestock and income for pastoral households. It is another increasingly significant non-food intervention that is carried out to increase household resilience to drought and rising food commodity prices [2]. Despite a large number of smallholder farmers in Kenya being aware and exposed to different fodder crops, only 55% of the farmers cultivate at least one type of fodder in their farms [3].

Kenya is experiencing severe fodder shortages estimated to be 70 percent of the country's yearly fodder requirements of over 5.5 billion bales being met by imported fodder. The deficiency is due to insufficient fodder supply and conservation, as well as overgrazing, poor land management techniques and climate change effects [4]. Additionally, land subdivision as a result of the land inheritance rules, rapid growth in population and the government's resettlement strategy; have put a strain on animal feed resources in the county [4]. Due to the developing demand for fodder by neighboring countries, the overall fodder demand is projected to increase. To produce this amount of fodder, an extra 15 million acres of land would need to be converted to fodder crops and pastures; however, this could be achieved by moving to dry and semi-arid regions. It is consequently recommended that unless targeted strategic fodder interventions are executed on a national scale, livestock productivity is likely to be affected leading to reduced yields of animal products in the medium and long term [5].

Farmers in Homa Bay County, Kenya are progressively adopting fodder production not only to address pasture shortage, which is mainly caused by recurrent droughts, but also to supplement earnings generated from livestock production. Several efforts have been initiated by different programs like Accelerated Value Chain Development (AVCD), CIAT, KALRO and County Governments with the help of the International Livestock Research Institute (ILRI), towards promoting fodder production with a view to increase milk production and improve household income. Rachuonyo East and South sub-counties were among the sub-counties that benefited from this program. Inputs utilization in fodder production in Homa Bay County is still unknown. This paper therefore intends to analyze the level of technical efficiency and its determinants that have not been evaluated in the county.

2. Literature Review

Different factors have an influence in the production of agricultural commodities. Such factors include the market factors, socio-economic characteristics, institutional and external factors. The socio-economic factors that affect the production of fodder include age, gender, level of education, experience, off-farm income, farm size and household size [6]. Institutional characteristics that have an influence on production of fodder include; access to extension services, membership to a fodder group, land ownership, credit access, contractual arrangements, infrastructure, government policies and laws. The external factors that the farmers have no control over include natural calamities (flood, drought, fire outbreak, inversion of pests), which also influence agricultural production. There are market factors that influence agricultural production such as the prices of output, means of transport and distance to the market [7].

Lugusa [8] found that in Southern Kenya, financial revenues of three range grasses were affected by persistent droughts, termite invasion and seed loss. The primary challenge for fodder production among smallholder farmers is the inadequate availability of land. This requires intensification and commercialization of fodder production [9]. The total household land size determines the land availability and size that a producer can assign to the production of fodder. Farmers in Mexico strongly agreed that land availability and the need for land to be fertile are necessary to use improved grassland [10]. Households owning bigger tracts of land are able to set aside some space for fodder production. These households are more likely to benefit from producing in large quantities that result in lowering production cost and increasing fodder production [7].

Household size is important in determining the level of fodder production since labor is mostly provided by the family. Production is more in larger families as compared to smaller ones [8]. The age of a household decision-maker is also considered a key aspect influencing the access to and availability of fodder production and livelihood resources [8] [11]. The head of households is more likely to be richer at above 35 years of age than those who are young, raising their probability of uptaking new technologies in fodder production.

Gender of the household decision maker is important in determining access to assets and resources mainly in the African rural setting. In sub-Saharan Africa, households headed by males have more access to factors of production like land, livestock and finance as compared to households headed by female. This is due to the fact that males are household heads as well as have land rights that make them access these resources [12]. Omollo *et al.* [13] found that 74 percent of fodder producers were headed by males while 55.3 percent were headed by females in Baringo and Makueni counties. Further, gender of the household decision maker was significant and had a positive ($p < 0.05$) influence on household's participation in fodder farming. This implies that households headed by male were more likely to adopt fodder production as compared to those headed by female [13]. This can be clarified due to the fact that the males have more access and control over the factors of production such as land, livestock and finance than the females [14] [15]. Moreover, this outcome can be linked to the increasing labor requirement of fodder production and the household tasks of women in the society. This limits their time to access information during agricultural trainings and extension provision [16] [17] [18]. Marginal effects indicate that encouraging participation of gender in fodder production can increase the chance of fodder production uptake by 20% [13].

3. Research Methodology

3.1. Study Area

This study was undertaken in Homa Bay County, Kenya. Homa Bay is located in Western region of the country, alongside the south shore of Lake Victoria lying at latitude of 0.6833˚S and longitude of 34.4500˚E. Homa Bay County is covering an area of approximately 3183.3 sq. km, having a population of 1,131,950 (male—539,560 and female—592,367), and according to the 2019 National Census [19]. The County is located about 420 km from Nairobi. It is bordering Migori county to the south, Kisii county and Nyamira to the east, Kisumu county to the north and Kericho county to the northeast. Homa Bay County is also bordering Lake Victoria to the north and west. Figure 1 indicates the map of the study area.

3.2. Sample Size

The sample size was determined using the formula given by Kothari [20] as

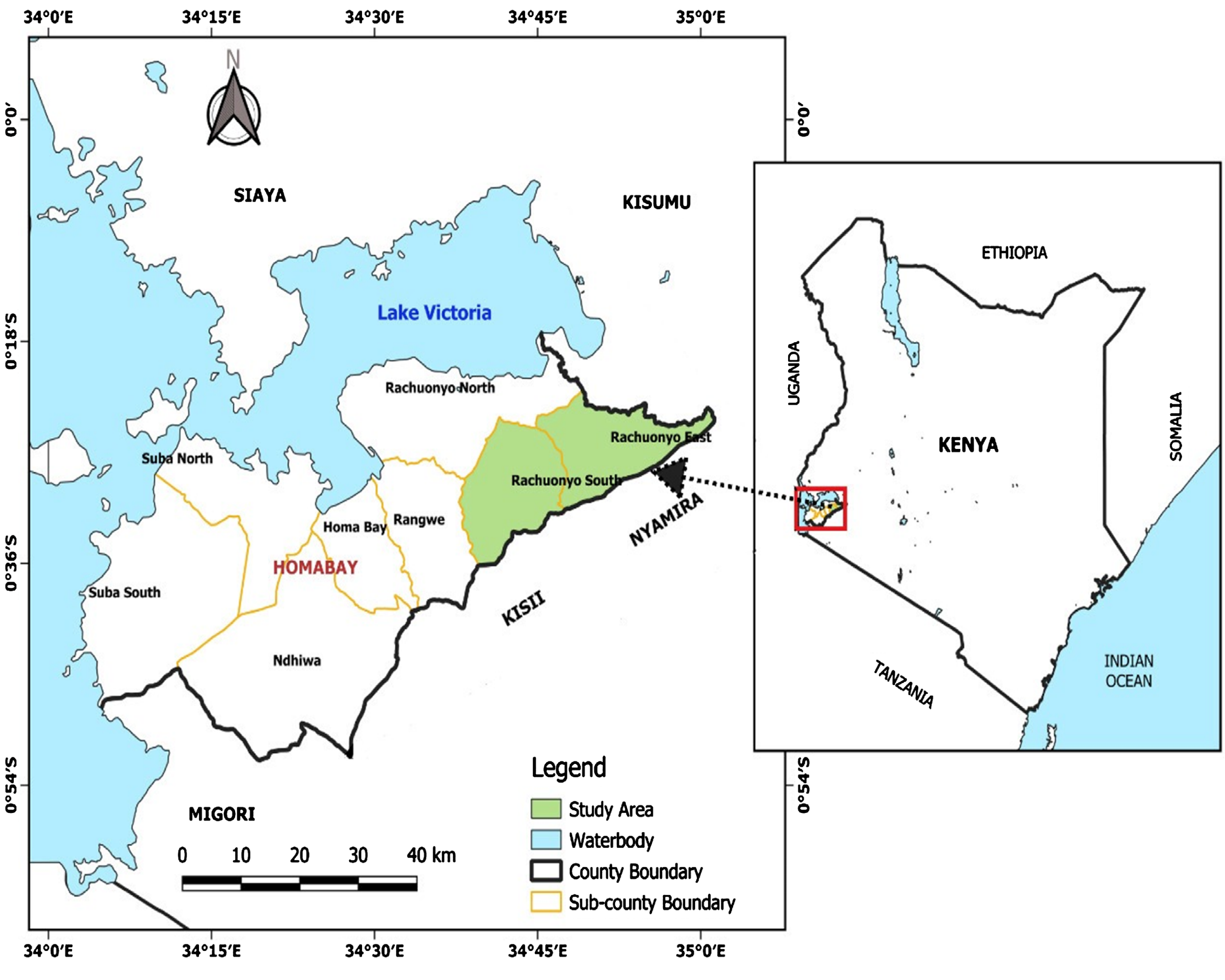

Figure 1. Map of the study area.

illustrated below:

$$n = \frac{pqZ^2}{E^2} \tag{1}$$

where; n = required sample size; Z = confidence level ($\alpha = 0.05$); p = proportion of the sample containing the major interest; $q = 1 - p$ and E = margin of error. Since the proportion of the population is not known with certainty, $p = 0.5$ is the assumption and $q = 1 - 0.5 = 0.5$, $Z = 1.96$ and $E = 0.0566$ (acceptable error term). According to Kothari [20], an error term of less than 10% is acceptable. Hence, the study used an error of 0.0566. This error was chosen so as to get the desired sample size that was able to fit the budget and the time duration for the study.

$$\frac{1.96^2 \times 0.50 \times 0.50}{0.0566^2} = 300$$

A sample of 300 farmers was selected from a population of fodder farmers in the two sub-counties. The 2019 Kenya National Bureau of Statistics (KNBS) data on the population of dairy cattle farmers in the 2 sub-counties of interest (clusters) was used. A proportionate to population size of respondents for each sub-county was computed to get 300 respondents (**Table 1**).

3.3. Empirical Model

To achieve this objective, Stochastic Frontier Model was used. Various functional forms namely; Translog, Cobb-Douglas, quadratic and linear functions can be used [21]. Cobb-Douglas and the Translog functions are mostly used. Translog function is flexible though multicollinearity problems may show up. Cobb-Douglas functional form was used since its simple, self-dual and has been broadly used in agricultural production technologies in various countries that are still developing [22]. According to Battese and Coelli [23], the following stochastic frontier production function of Cobb-Douglas model was used in the estimation of technical efficiency of fodder production.

$$\ln Y_i = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \cdots + \beta_n \ln X_n + V_i - U_i \tag{2}$$

where ln is the natural logarithm, $i: 1, 2, 3, \cdots, n$, Y_i is the total quantity of fodder production in 90 kilograms, β_0 is the constant term, $\beta_1 - \beta_n$ parameters to be estimated, $X_1 - X_n$ vectors of explanatory variables (amount of fertilizer used, labor, planting material and farm size), V_i is a symmetric random error and U_i is half normal error term. Equation (2) above was estimated using the maximum

Table 1. Distribution of sample size.

Sub-County	Households	Proportion	Proportionate per Cluster
Rachuonyo East	1161	0.59	177
Rachuonyo South	813	0.41	123
Total	**1974**		**300**

Source: KNBS, 2019.

likelihood estimates (MLE).

Technical efficiency (TE) was computed as the ratio of the observed output Y_i to the frontier output Y_i^*.

$$TE_i = \frac{Y_i}{Y_i^*} = \frac{\exp\left(X_i\beta + V_i - U_i\right)}{\exp\left(X_i\beta + V_i\right)} = \exp\left(-U_i\right) \tag{3}$$

where TE_i was the technical efficiency of farmer i, Y_i was the fodder output observed, Y_i^* was the maximum potential fodder output. This model was estimated with the use of stochastic production function and the Maximum Likelihood Estimates (MLE). FRONTIER 4.1 which is a computer program was used in the estimation of parameters of the stochastic production function and the effects of technical inefficiency. Once the socio-economic characteristics of the fodder farmers and technical efficiency of production was determined, farm inputs variables expected to cause variation in fodder production efficiency were tested as the determinants of the technical efficiency. The explanatory variables were chosen based on past empirical studies or intuition. The level of TE of the farmers was regressed on these factors for the purpose of determining the contribution made by each variable [24]. Since technical efficiency scores range from 0 to 1, a Tobit regression model with two limits was used to analyze the link between socio-economic and institutional factors on technical efficiency. A two-step method that is frequently utilized was applied in this study. The first step was to estimate the technical efficiency scores by using the Stochastic Frontier Model. Second step was to regress the technical efficiency scores on farmer characteristics variables to detect their impact on technical efficiency.

$$U_i^* = \beta_0 + \sum\nolimits_{j=1}^{k} \beta_j Z_{ij} + \mu_i$$

$$\begin{cases} 1 \ \text{ if } U_i^* \ge 1 & (4) \\ 0 \ \text{ if } U_i^* \le 1 & (5) \end{cases}$$

where U_i^* is the efficiency scores of the i^{th} famer, β_0 is a constant, β_j are the parameters to be estimated, u_i is the error term, Z_{ij} are farm and farmer characteristics variables. Table 2 and Table 3 list the variables used in the model.

Table 2. Variables used in Stochastic Frontier Production Model

Variable	Description	Expected sign
Dependent variable		
Output (Y)	Total fodder output (kgs)	
Explanatory variable		
FrmS	Land under fodder (acres)	+
Plantmat	The quantity of planting materials used in kgs	+/−
Llprep	Labor for land preparation (man hours)	+/−
Lpln	Labor for planting (man hours)	+/−
Lwed	Labor for weeding (man hours)	+/−

Table 3. Variables used in two-limit regression model.

Variable	Description	Measurement
Dependent variable		
Technical efficiency (U)	Technical inefficiency measures	Between 0 and 1
Explanatory variable		
Age	Age of household head	years
Gender	Gender of household head	male = 1, female = 0
Hhs	Household size	Number
EducLev	Education level of the household head	years
GrpM	Group membership	yes = 1, no = 0
HrdS	Number of dairy cattle owned by a farmer	Number
Acc	Credit access	yes = 1, no = 0
Ext	Access to extension services	yes = 1, no = 0
Trn	Training on fodder production	yes = 1, no = 0

4. Results

4.1. Stochastic Production Frontier Estimates

A stochastic frontier model was used to analyse the level and determinants of technical efficiency of fodder farmers. The dependent variable was the quantity of Napier grass produced in 90 kg bags while independent variables used were land size under fodder, quantity of planting materials, and labor in man days for land preparation, labor in man days for planting and labor in man days for weeding.

Table 4 presents the results of Maximum Likelihood Estimates (MLE) of the Cobb-Douglas stochastic production function of fodder farmers. The diagnostic statistics such as Sigma-squared, Wald chi-square and log likelihood are presented together with the results of efficient use of resources (TE). The Wald Chi-square statistic (3425.90) is statistically significant at 1%, with the implication that all the variables that were included in the stochastic production function jointly influenced fodder output.

Results indicate that Sigma-squared is 0.1132, hence lies between 0 and 1. A value of Sigma-squared equal to 0 implies that technical inefficiency is not present while a value that is close to 1 implies that the stochastic frontier model used is appropriate. In addition, the value of Sigma-squared is a measure of composite error distribution and the measure of goodness of fit. The value of lambda is 1.3442 and is found to be statistically significant at 5 percent significant level. This is an implication that 134% of the variation in fodder output is attributed to inefficiency. The value of log likelihood was found to be 13.7709 and is found to be statistically significant at 1 %, hence indicating the presence of inefficiency in the data.

Table 4. Maximum Likelihood Estimates for Stochastic Frontier production function.

Variable	Coefficient	Std. Err	Z-value	p > /z/
Ln_Land size under fodder	0.515***	0.069	7.47	0.000
Ln_Quantity of planting materials	0.257***	0.073	3.54	0.000
Ln_Labor for land preparation	0.228	0.041	0.55	0.582
Ln_Labor for planting	0.102*	0.059	1.74	0.082
Ln_Labor for weeding	0.202***	0.055	3.67	0.000
Constant	3.495	0.225	15.56	0.000
/lnsig2v	−3.211	0.251	−12.78	0.000
/lnsig2u	−2.619	0.407	−6.44	0.000
Sigma_v	0.201	0.025		
Sigma_u	0.270	0.055		
Sigma-squared	0.113	0.022		
Lambda	1.344	0.077		
Number of observations = 225		Wald Chi^2 (5) = 3425.90		
Log likelihood = −13.7709		Prob > Chi^2	=0.0000	

*, **, *** significant at 10%, 5%, 1%.

The results indicate that the sum of the partial elasticity of the factor inputs is 1.304. A function coefficient of less than 1 indicates decreasing returns to scale while a function coefficient of more than one indicates increasing returns to scale. On the other hand, a sum of the partial elasticity of 1 indicates constant returns to scale. Elasticity of 1.304 implies that if all the inputs in Table 4 are increased by 1 %, the fodder output would increase by 1.304%. This means that most of the farmers were in stage one of the production region, hence every proportionate increase in unit of factor of production result in more than proportionate increase in fodder output for the farmers. This means that farmers have the potential to increase their production, thus they are not efficient in allocation of resources. In other words, the increasing return to scale implies that the production is inefficient with a room to increase production at an increasing rate.

The coefficients of land size under fodder, quantity of planting materials used, labor in man days for planting and labor in man days for weeding were all positive, indicating that all these inputs were used in the rightful proportions. In addition, the positive coefficients of these inputs, *ceteris peribus*, would increase the total fodder output.

The coefficient of land size under fodder was positive and statistically significant at 1%, implying that a percent increase in land size would increase the fodder output by 0.515. The higher elasticity of land size indicates that land size has a strong significant effect on fodder output. This finding is similar to Orewa and Izekor [25] that farm land expansion increases the technical efficiency of yam farmers in Edo State, Nigeria. However, this finding is different from Desale [26] that as the farm size increases, the management ability of farmers' decrease given the existing technology, and hence leading to reduced level of efficiency.

The coefficient of quantity of planting materials was positive and statistically significant at 1% level. This result indicates that a percentage increase in quantity of planting materials increase fodder output by 0.257. The yield of fodder was higher with large quantities of planting materials used. This is possible since good planting materials as well as quality seeds are able to improve the production of fodder. This is similar to Kibaara [27] which revealed that improved efficiency of agricultural production output is significant especially in overcoming problems of low yields by enhanced supply of improved seed variety.

The coefficient of labor for planting and weeding was statistically significant at 10% and 1% level, respectively. This implies that a percentage increase in the number of days by farmers in planting and weeding increases the fodder output by 0.102 and 0.202, respectively. An increase in the number of man-days would increase fodder output because of improved husbandry practices. This concurs with Obayelu *et al.* [28] that the availability of family labor provides more man days hence reduces labor constraints especially during peak of the planting season. The coefficient of labor for land preparation was positive but insignificant on the amount of fodder output.

4.2. Distribution of Technical Efficiency Scores of Fodder Farmers

Table 5 presents technical efficiency scores for a sample of 225 fodder farmers in Homa Bay County.

The results indicate that the best performing fodder farmer had a technical efficiency score of 0.8 (80 percent) while the least performing farmer had a technical

Table 5. Technical efficiency scores distribution.

TE scores	Freq.	Percent
0 - 0.2	0	0
0.2 - 0.4	5	2.22
0.4 - 0.6	65	28.89
0.6 - 0.8	155	68.89
0.8 - 1	0	0
Total	**225**	**100**
Mean 0.7333		
Min 0.4		
Max 0.8		
Std.Dev. 0.1035		

score of 0.4 (40 percent). The mean efficiency score of farmers was about 0.7333. None of the farmers had technical efficiency scores between 0 to 0.2 and 0.8 to 1. Results further indicate that majority of farmers (69 percent) had technical efficiency scores ranging from 0.6 (60 percent) to 0.8 (80 percent), while minority (2 percent) had technical efficiency scores ranging from 0.2 (20 percent) to 0.4 (40 percent). The higher technical efficiency scores for majority of the farmers could be attributed to higher number of man days allocated during planting and weeding as well as the proportion of land that is allocated for fodder production.

4.3. Factors Affecting Technical Efficiency among Fodder Farmers

Table 6 indicates the sources of variation in technical efficiency scores among fodder farmers. The technical efficiency scores presented in Table 5 was regressed against the farmer characteristics to get the variation presented in Table 6. Farmer and farm characteristics were treated as independent variables while technical efficiency scores of each farmer were considered as dependent variable using Tobit model. Some of the variables that provided positive and significant coefficients include total herd size, group membership and access to credit while household size and access to training had negative significant influence on technical efficiency of fodder farmers. Results indicate that Tobit model explained about 68.9% of the variations in technical efficiency of farmers. The estimated probability was higher than the Chi-square value (Prob > Chi^2 = 0.0017), implying that the model has perfect goodness of fit with a strong explanatory power.

Table 6. Two-Limit Tobit regression analysis results.

TE scores	Coef.	Std.err.	t-value	p-value
Age_Hh	0.0007	0.0007	0.93	0.351
Gender	0.0222	0.0152	1.46	0.145
Years of schooling	−0.0017	0.002	−0.85	0.398
Household size	−0.0092**	0.0041	−2.26	0.025
Total herd	0.0083**	0.0037	2.25	0.025
Group membership	0.0429***	0.016	2.68	0.008
Extension	0.0032	0.0178	0.18	0.859
Training	−0.0282*	0.0155	−1.82	0.070
Access to credit	0.0258*	0.0138	1.86	0.064
Constant	0.7046	0.0478	14.72	0.000
Sigma	0.0974	0.0046		
Log likelihood=		204.76595		
Prob > Chi^2=		0.0017		
Pseudo R^2=		−0.0689		
LR Chi^2 (9)=		26.41		

Household size was found to be negatively significant on technical efficiency of fodder farmers at 5% level. An increase in household size by one unit decreases the level of technical efficiency of farmers by 0.9%. Farmers with large household size are able to share the benefits of farming in food consumption and income needs, hence leaving less benefit to finance fodder farming. This is similar to the findings by Ndubueze-Ogaraku *et al.* [29] which showed that household size had a significant negative influence on technical efficiency. However, this finding contradicts Besseah and Sangho [30] which indicated that household size had a negative significant impact on technical efficiency of cocoa farmers in Ghana. A possible reason is that farmers with large household size have enough labor that would be available to carry out many farming activities, hence making production activities efficient.

Total herd size was positively significant at 5% level, implying that for every additional increase in the number of herd size, the technical efficiency would increase by 0.8%. A possible reason is that fodder production is dependent on the number of herd that the farmers own, hence farmers with large herd size would be interested to invest more in fodder production to meet the animal feed needs. In addition, ownership of livestock makes farmers to invest in purchasing fodder since herd size is directly related to the feed demand. Another possible reason is that cattle herd is considered as a capital asset hence it can be easily liquidated in meeting some of the expenditure needs including livestock and family needs [31]. This finding is in conformity with Otieno *et al.* [32] which argued that beef herd size is shown to have a positive significant effect on technical efficiency of farmers in Kenya.

Membership to group was found to be positively significant at 1% level. This means that farmers who belong to group increases technical efficiency by 4.3%. One of the possible reason is that group membership provides farmers with social capital hence they can pool resources for collective action. In addition, group membership makes farmers to exchange ideas as well as learn about the ideas concerning benefits of fodder production. Some of the reasons why group membership increases technical efficiency of farmers include, group membership enhances access to fodder for livestock, trainings, joint input purchase, group marketing and alternative income sources [33]. Instances where farmers are able to work together in groups, new skills are able to be developed including, skills in managing groups, technical skills, economic cooperative, problem solving skills, book keeping, grass root democracy [34]. This would potentially make fodder farmers have market oriented production, hence diversify their incomes and increase their production.

Access to training had a negative significant influence on technical efficiency at 10% level. This implies that access to training decreases the technical efficiency of farmer by 2.8%. These trainings could be done by semi-skilled professionals that do not have adequate content on fish production. As a result, these farmers did not obtain adequate training services, particularly on agronomic practices that are related to fodder production, hence making training services inefficient. For other reasons, farmers who got training services were trained on other crops other than fodder, making fodder production inefficient. This finding is however different from the study by Dessale [26] who argued that training is important in building the management capacity of most of farmers. Training of farmers improves skills in using improved seeds, postharvest handling, resource management, farm management as well as other farm productivity. In addition, training services are designed to enlighten the farmers on the benefits of group membership, coupled with effective extension services in delivering capacity building in using production inputs and access to credit facilities that are necessary in increasing technical efficiencies.

Access to credit was positively significant on technical efficiency at 10% level. This indicates that access to credit increases technical efficiency by 2.6%. Credit is important to farmers in purchase of inputs used in fodder production, purchase of production facilities such as fertilizers, planting materials and bailing equipment. In addition, credit makes fodder farmers to meet their cash needs in the production cycle. Farmers who have access to credit is important in improving the incomes of farmers by mobilizing resources thus they would have more productive resources. Moreover, credit increases the efficiency of farmers since it capable of solving shortage of liquidity capital. In addition, availability of credit is capable of shifting the cash constraint outwards, hence would make farmers to make purchases that they could not afford using their own resources as well enhance the use of agricultural inputs hence leading to more technical efficiency. The finding is similar to the study by [26] [35] [36] that found a positive significant relationship between access to credit and technical efficiency. The findings from this study reveal the technical efficiency of farmers by having better allocation of some of the available resources that including land allocated for fodder, quantity of planting materials as well as labour for land preparation and planting.

5. Conclusion

The findings establish that inputs used in Napier grass production had an elasticity of about 1.304%, implying that farmers were in stage one of production. These farmers have the potential to increase their production, hence are not efficient in the allocation of their resources. Land size under fodder, quantity of planting materials used, labor in man days for planting and labor in man days for weeding were all positively influencing the farmer's level of technical efficiency scores in fodder production. The higher elasticity of land size implies that land size had a strong significant effect on fodder output. It was important to note that majority of the farmers had higher technical efficiency scores implying that Napier grass production has the potential of improvement both in the short run and in the long run. Further, results from Tobit model indicated that total herd size, group membership and access to credit were positive and significant on technical efficiency among fodder farmers. On the other hand, household size, and access to training was found to be negative and significant on technical efficiency among these farmers.

6. Recommendations

Farmers need to increase land under fodder, planting materials and the number of man days during planting and weeding since they were significant in increasing farmers' fodder output. In addition, the Government and input suppliers should ensure that the planting materials are readily available to Napier grass farmers at affordable prices. These planting materials should be of good quality so as to improve the production of fodder. Furthermore, there should be efficient distribution of these materials to ensure that they are accessible to all farmers. Farmers should be encouraged to join some of the existing fodder groups through which training and extension services are provided.

Conflicts of Interest

The authors declare no conflicts of interest.

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