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Determinants of sorghum productivity among small-scale farmers in Siaya County, Kenya

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The productivity of sorghum in Kenya is on decline despite sorghum being one of the suitable crops for the arid and semi-arid areas commonly found in Kenya. The study therefore aimed at establishing the effect of the selected socio-economic factors on sorghum productivity using a case of small-scale farmers in Siaya County. The four sub-counties considered for this study were selected on the basis of sorghum production. Stratified and random sampling techniques were applied to identify a sample comprising of 300 smallholder households in the study area. Data was collected using semi-structured interview schedules administered to the selected farm households. The characteristics of the smallholder farmers sampled were analyzed using descriptive statistics and Ordinary Least Square multiple regression model. The results showed that farm size under sorghum, labour, farm gate price, serena and seredo seed varieties were significant determinants of sorghum productivity in the study area. Based on these findings, the study recommends provision of improved seed varieties to the farmers. Policies targeted at promoting industrial use of sorghum will increase sorghum demand and promote its uptake. In addition, agricultural development policies should target provision of such services like training and extension support to enhance sorghum production in Kenya.

Key words: Sorghum productivity, arid and semi-arid, ordinary least square.

INTRODUCTION

Sorghum is one of the major cereal crops globally and is ranked fifth after maize, wheat, rice and barley in terms of production and importance (Naik et al., 2016). It is mainly grown in Central America, Africa and Asia primarily to enhance food security (Hassan, 2015). Globally, sorghum serves as a stable food for not less than 500 million people living in arid and semi-arid lands of Asia and Africa (Teferi, 2013). On average, sorghum constitutes 20% of the total cereals produced in Africa (Dube et al., 2014). Africa produces on average 20 million metric tons of sorghum which is a third of the global production of 60 million metric tons (Dube et al., 2014). In Eastern and Central Africa, sorghum cultivation covers an area close to 10 million ha. Nigeria is the leading sorghum producer in Africa at 34% seconded by Sudan at 21% (Mitaru et al., 2012). Other countries like Ethiopia, Tanzania, Uganda, Rwanda and Kenya account for 7, 4, 2, 0.8 and 0.6% respectively of sorghum produced in Africa (Mitaru

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et al., 2012).

Approximately, 43% of total landmass in Sub-Saharan Africa is arid and semi-arid and this is expected to increase as a result of climate change (Hadebe et al., 2017). In Sub-Saharan Africa, the predominant source of livelihood is rain-fed agriculture, mainly practiced on small-scale by smallholder farmers (Mavhura et al., 2015). Farmers usually realize very scanty yields from this system of farming especially during extreme drought periods (Mabhaudhi et al., 2017). It has been estimated that between 70-85% of the poor Africans entirely depend on agriculture for livelihood (Byerlee et al., 2005; Ravallion et al., 2007). It has also been reported that rural livelihoods face major food insecurity menace, 83% of the population being in the extreme poverty trap (FAO, IFAD, and WFP, 2014). Thus concerted efforts towards increasing agricultural productivity are necessary in Sub-Saharan Africa. There is still high potential of increasing both agricultural productivity and land productivity sustainably in this region, however, the fundamental question lies on how the Sub-Saharan Africa will realize its production potential (Conceição et al., 2016). One of the major entry point towards increasing agricultural production is the knowledge on food production dynamics especially in arid and semi- arid areas where small – scale farming is the major farming system, and farmers are less adaptive to climate change (Chivenge et al., 2015; Mundia et al., 2019). Sorghum plays a crucial role in providing food security in the face of climate change in many developing countries (Ogeto et al., 2013; Mundia et al., 2019).

Globally, there has been a positive growth in per capita food production over decades except in Africa where there is a steady decline in food production. Yield gap is therefore a major concern given that the global crop and food demand is projected to rise by more than 50% in 2050 (Pradhan et al., 2015). Arguably, since rain-fed agriculture occupies more than 95% of agricultural land use in Sub-Saharan Africa and water insufficiency is a real challenge, crops such as sorghum becomes major alternative crops in these regions since they are drought tolerant, require relatively less water, have high varieties of germplasm, have higher nutritional value (Hadebe et al., 2017), resistant to pest and diseases and adaptive to harsh arid and semi-arid environment (Chibarabada et al., 2017) as well reducing micro-nutrient mal-nutrition among farming households (Muui et al., 2013; Govender et al., 2017). Despite its potential in driving Sub-Saharan Africa towards sustainably increasing its food reserves, sorghum is under-utilized and production is still low (Orr et al., 2016; Grovermann et al., 2018). In some cases, sorghum has been associated with poverty, that is, some farmers tend to perceive sorghum as food for the poor (Dicko et al., 2006). These social factors together with other socio-economic and climatic factors have compounding effect on reducing uptake of sorghum as well as its production (Grovermann et al., 2018). In addition, Mwadalu and Mwangi (2013) pointed out that small – scale farmers have limited access to various institutional infrastructures such markets perpetuated by inadequate extension services and commodity processing facilities which negatively impact farm performance. Similarly, Rezig et al. (2010) highlighted that smallholder farmers are under- capacitated and face myriad of challenges, both biophysical and socio-economic in nature. Such constraints include low credit access, less fertile soils, inaccessibility to improved seed varieties and unreliable rainfall among others. This explains why low input agricultural systems, such as those of sorghum among other underutilized cropping systems, become essentially important in Sub- Saharan Africa (Rezig et al., 2010).

In contrary, the existing policies, Non-Governmental Organization aids and research on food crops generally tend to give high priority to major crops such as maize and as such encouraging production of crops less adapted to arid and semi-arid areas (Mukarumbwa and Mushunje, 2010; Pingali, 2015). Enhancing crop diversification through active inclusion of underutilized and drought tolerant crops such as sorghum and millet in order to boost farmer resilience and adaptive capacity to climate change are important across Africa and Asia (Fischer et al., 2016). As a result, there is need for a paradigm shift with respect to government agricultural policy setting, research and funding, meaning that, focus should be on diversified agriculture rather than agricultural system that promote a few selected crops (Massawe et al., 2015; Fischer et al., 2016; Mabhaudhi et al., 2017). A change in policy should promote climate responsive agriculture that encourages production of drought tolerant crops in arid and semi-arid areas in developing countries (Fischer et al., 2016). In addition, realization of sustainable food production will require that the aim of the current research should go beyond improving production but also to matching crops with the suitable agro-ecology (Sebastian, 2009).

In Kenya, sorghum is mainly grown in Nyanza, Eastern and Coastal regions which are frequently affected by drought and crop failure. Sorghum being an indigenous crop in Kenya is more suitable in salvaging households from hunger and poverty (Muui et al., 2013). However, the production of sorghum is on decline and the yields obtained by farmers are at unsatisfactory levels of 0.85 tons per hectare (Muui et al., 2013). The acreage apportioned to sorghum is also low compared to other crops such as maize (Kilambaya and Witwer, 2013). Similarly, the production of sorghum and millet is below the consumption demand (Recha, 2018). Masese et al. (2018) indicated that there is sorghum consumption deficit of more than 60 metric tons. The yield gap stands at approximately 70 000 tons due to decline in national sorghum production from 189 000 tons in 2015 to 117 000 metric tons in 2016 (Food and Agricultural Organization Statistics (FAOSTAT), 2018).

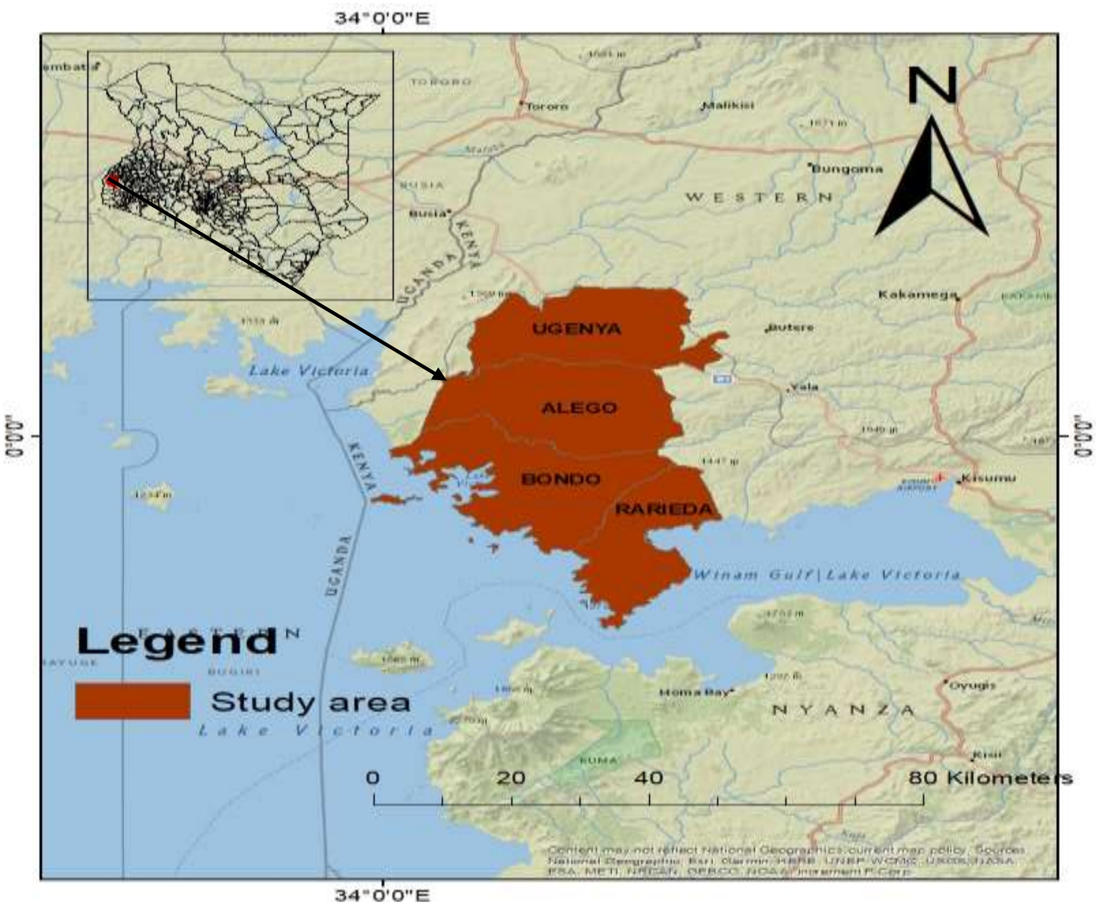

Figure 1. Map of the study area.

Several interventions have been made towards increasing sorghum production. Such interventions include release of drought, disease and pest tolerant High Yielding Sorghum Varieties (HYSVs) by research institutions like the International Crop Research Institute for Semi-Arid Tropics (ICRISAT). However, optimal sorghum production has not been achieved, implying increasing production does not necessarily rely on new technology uptake alone (Karanja et al., 2009). Production variations among farmers may be due to differences in regional settings and socio-economic characteristics of the farmer (Chimai, 2011). It is equally important to note that, despite their importance, there is inadequate research based information on underutilized crops such as sorghum (Mukarumbwa and Mushunje, 2010; Mabhaudhi et al., 2016; Orr et al., 2016; Mabhaudhi et al., 2017; Mundia et al., 2019) since most research have been focused on major cereal crops such as maize, rice and wheat. The study therefore aims to analyse the effect of the selected factors on the overall sorghum productivity unlike the previous studies that were specific to the effeciency of production (Chepng'etich et al., 2014, 2015; Zalkuwi et al., 2015; Naim et al., 2017; Okuyama et al., 2017; Botiabane et al., 2018).

METHODOLOGY

Description of the study area

The study was conducted in Siaya County. The county is located in Nyanza region, western Kenya. It borders Kakamega and Vihiga counties to the north-east, Busia County to the north, Kisumu County to the south-east and Lake Victoria to the south. The area lies between latitude 0°26' to 0°18' north and longitude 34°58' east and 33°33' west (Figure 1). The population of the county is approximately 841,682 people (GoK, 2009). The predominant agro-ecological zone (AEZ) in the county is lower midland zones (LM) starting from LM 1 up to LM 5 with traces of upper midland zones (UM) in areas with high agricultural potential (MoALF, 2016). The area is characterized by an annual mean temperature of 22.3°C with rainfall ranging from 900 to 1500 mm per year. Soil types range from low nutrient soil to red volcanic soil in some areas. Some of the major crops grown include maize, sorghum, beans, cowpeas, millet, sweet potatoes, groundnuts, cotton and sugarcane (MoALF, 2016).

Research design and sampling procedure

The study employed cross-sectional survey design. This research design enables the researcher to collect data at single point in time. The study applied a combination of two-stage stratified random sampling and probability proportionate to size sampling techniques in selecting the sample households. In the first stage, the four sub-counties were selected purposely on the basis of sorghum production. Once the sub-counties had been selected, a two-stage stratified sampling technique was applied to select one ward and subsequently one village from each ward in every sub-county selected. Finally, households were randomly selected from each of the randomly selected villages to achieve the target sample size. The number of households selected from each village was determined by the population of that village.

Data collection, sample size and analysis

Data for this study was collected using semi-structured interview schedules. A total of 300 farmers from the selected households were interviewed from the three sorghum producing sub-counties, namely; Rarieda, Bondo, Alego and Ugenya (Figure 1). Prior to data collection exercise, the data collection instruments were tested both for validity and reliability using a sample of 20 interview schedules administered to 20 randomly selected households. By applying split-half method, the instrument yielded a reliability coefficient of 0.7, thus proving reliable. The items found to be ambiguous and inadequate were correctly worded and re-modified to improve clarity. This study used primary data. The information collected was on household demographics such as gender, age, education, household size, total monthly income, off-farm income; farm characteristics such as yields, labour, farm experience and farm size and institutional factors such as extension contact, training, group membership, market access, road access, credit access and seed varieties. The data collected was analyzed using descriptive statistics (mean) and Ordinary Least Square (OLS) applied for descriptive and quantitative analysis respectively.

OLS model specification

Stochastic OLS multiple regression model was used to determine the effect of the selected factors on sorghum productivity. OLS is the most widely used economic model in estimating beta (β) parameters in several quantitative analysis (Rutherford, 2001). OLS multiple regression model shows the relationship between multiple independent variables and a continuous dependent variable. It is regarded as one of the most powerful statistical model in statistical analysis because of its relative simplicity in checking model assumptions such as linearity, constant, variance and the effect of outliers (Hutcheson and Sofroniou, 1999). The model shows the magnitude of the effect of the independent variable on the dependent variable. OLS model is linearly specified in the form;

$$Y_i = \beta_0 + \beta_i X_i \dots \beta_n X_n + U_i \quad (1)$$

Where Y_i is the dependent variable, β_0 is the intercept, $\beta_i \dots \beta_n$ are the coefficients of explanatory variables, $X_i \dots X_n$ are the explanatory variables while U_i is the error term. Based on Equation 1, we specified our model as;

$$Y_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \beta_{10} X_{10} + \beta_{11} X_{11} + \beta_{12} X_{12} + \beta_{13} X_{13} + \beta_{14} X_{14} + \beta_{15} X_{15} + \beta_{16} X_{16} + \beta_{17} X_{17} + \beta_{18} X_{18} + \beta_{19} X_{19} + \beta_{20} X_{20} + U_i \quad (2)$$

Where, Y_i represents sorghum quantity (dependent variable) X_1 represents age (years), X_2 represents gender of respondent (years), X_3 represents education of respondent (years), X_4 represents household size (number of household members), X_5 represents total monthly income (KES), X_6 represents monthly off-farm income (KES), X_7 represents land size (acres), X_8 represents labour (man days), X_9 represents hired labour (man-days) X_{10} represents family labour (man-days), X_{11} represents farm gate price (KES), X_{12} represents market distance (kilometres), X_{13} represents land ownership (dummy), X_{14} represents credit access (dummy), X_{15} represents training access (dummy), X_{16} represents seredo variety (dummy), X_{17} represents gadam variety (dummy), X_{18} represents serena variety (dummy), X_{19} represents ochuti variety (dummy), X_{20} represents nyakabar variety (dummy), β_0 to β_{19} are the parameters to be estimated and U_i is the error term, randomly distributed.

RESULTS AND DISCUSSION

Descriptive statistics

The selected variables for the study were summarized and presented in Table 1. On average, farmers produced 555.31 kg/acre which is approximately 0.555 tons/acre. This implies that the current sorghum production level in the area is far much below the potential output of 1.52 tons/acre (Muui et al., 2013) or 2-5 tons/acre (FAOSTAT, 2018). The mean age of the farmers was 47.13 which is comparable to the findings of several previous studies (Danso-Abbeam et al., 2018; Mmbando and Baiyegunhi, 2017; Suvedi et al., 2017; Ghimire et al., 2015); implying that farming is mostly dominated by the elderly. More male farmers (69%) than female farmer constituted the sample. The average years of schooling were 9 years with the majority of the sampled households constituting of 5 persons. Large family sizes are a likely implication that households have readily available farm labour derived from the family. Most of the households had a total monthly income of KES. 11, 336.68 and an average monthly off-farm income of KES. 8, 111.56. This shows that the largest share of the households' income come from off-farm income sources; implying that majority of the households depend on off-farm employment for livelihood alongside agriculture. Households allocated an average land size of 0.74 acres to sorghum. In regard to labour use, 65 man days on average was used in one acre of sorghum. The average farm gate price of sorghum per kilogram was KES. 32. In terms of proximity to the market, the average distance to the nearest market was 2 km. This implies that farmers incurred less transport cost when shipping the produce to the nearest market. In addition, since market and road distance can be used as proxy for input accessibility, nearness to the

Table 1. Descriptive results of variables and the expected effects on sorghum production.

Variable	Description	Mean	SD	Expected sign
Dependent variable				
Sorghum productivity	Quantity of sorghum in kilogram per acre	555.31	385.18	
Independent variable				
Age (years)	Age of the respondent in years	47.13	14.25	-
Gender	1, if the gender of the respondent is male; 0, if otherwise	0.69	0.48	+/-
Education (years)	Number of years spent in school by respondent	9.03	4.27	+
Household size	Total number of household members directly dependent on household head	5.40	2.80	+
Household income (KES)	Average total monthly income	11336.68	9057.48	+
Off-farm income (KES)	Average monthly off-farm income	8111.56	9278.24	+/-
Land size (acres)	Total farm size under sorghum	0.74	0.61	+/-
Labour (man-days)	Labour used per acre of sorghum	65.23	36.07	+/-
Farm gate price	Farm gate price of sorghum per kilogram	32.42	7.18	+/-
Market distance (km)	Distance to the nearest market	2.17	1.51	+/-
Land ownership	1, if the land under cultivation is owned by the household; 0, if rented	0.93	0.25	+/-
Training	1, if the household receives training; 0, if otherwise	0.41	0.49	+
Credit access	1, if the household has access to credit; 0, if otherwise	0.33	0.47	+/-
Seredo seed variety	1, if the household grows seredo variety; 0, if otherwise	0.45	0.50	+
Gadam seed variety	1, if the household grows gadam variety; 0, if otherwise	0.05	0.22	+
Serena seed variety	1, if the household grows serena variety; 0, if otherwise	0.05	0.21	+
Ochuti seed variety	1, if the household grows ochuti variety; 0, if otherwise	0.22	0.41	-
Nyakabar seed variety	1, if the household grows nyakabar variety; 0, if otherwise	0.05	0.23	-

Source: Own survey (2019); Note: 1 USD is an equivalent of KES. 100 at the time of the study; SD denotes standard deviation.

market increases farmers' access to farm inputs. In terms of land ownership, 93% of the households operated on own lands; implying that most households are able to adopt better farming systems and technologies due to high tenure security and absence of land rental fee. Most of the households (59%) did not receive farm related training. In regard to credit access, 67% of the sampled farmers reported lack of access to farm credit. This explicitly details limited existence of institutional services meant to improve agricultural production in the area. Compared to other varieties, seredo variety was the most adopted as represented by 55% of the farmers. Serena, gadam and nyakabar were the least adopted. Only 0.05% of the farmers produced these varieties.

The mean sorghum yield was high among male than female farmers (Table 2). Generally, women are more disadvantaged in regard to farm credit accessibility (Adebayo and Adenkule, 2016). The output quantity is always lower for women than men due to limited access to extension services, credit and capital among female farmers (Ayelech, 2011). These disparities in terms of access to production services explain the significant variations in production across different gender. We found a significant difference in the quantity of sorghum produced between family and hired labour (Table 2). This implies that the mean sorghum output was high for hired labour than family labour.

Multiple regression results

The regression analysis was done using the STATA software and OLS multiple regression model. The results of the multiple regression are given in Table 3 and discussed hereafter.

Multicollinearity test

Multicollinearity exists when the explanatory variables are highly linearly correlated such that it is quite difficult to differentiate between which independent variables (X) affect dependent variable (Y) (Midi et al., 2010). Existence or non - existence of multicollinearity is explained based on the values of Variance Inflation Factor (VIF). The VIF value of the predictor variables should neither be greater than 10 nor less than one (Gujarati, 2003). VIF value greater than 10 indicates multicollinearity (Allison, 2001). It can therefore be concluded that multicollinearity exist if the VIF values exceeds 10 or smaller than 1. The results presented (Table 3) showed that there was no multicollinearity since none of the variable had VIF less than 1 or greater than 10.

Table 2. Productivity comparison between gender, age groups and labour source.

Variable	Productivity per acre	SD	t	Sig.
Gender				
Male	606.21	334.44	1.681	0.094**
Female	513.04	407.25		
Age categories				
18 - 35	496.46	362.08	-1.186	0.237
> 35	568.69	389.01		
Labour source				
Family	433.05	272.18	-4.697	0.000**
Hired	736.64	449.98		

Source: Own survey (2019); *** Sig. 1%, ** sig. 5% and *sig. 10%.

Table 3. Multiple regression results on selected factors affecting sorghum productivity (kilograms of sorghum per acre).

Sorghum quantity	Coef.	Std. Err.	t	P > |t|	VIF
Social factors					
Age	-0.013	0.051	-0.26	0.796	1.14
Gender	0.018	0.014	1.27	0.205	1.16
Education	0.004	0.006	0.59	0.553	1.33
Household size	0.024	0.033	0.73	0.469	1.40
Household income	-0.018	0.025	-0.73	0.467	1.90
Off-farm income	-0.008	0.010	-0.78	0.439	1.15
Economic factors					
Land size	-0.824	0.060	-13.67	0.000***	6.95
Labour (man days)	0.170	0.062	2.76	0.006***	3.95
Hired labour	0.035	0.018	1.94	0.053*	2.33
Family labour	-0.002	0.016	-0.15	0.880	2.34
Farm gate price	0.389	0.017	23.53	0.000***	3.40
Institutional factors					
Market distance	-0.005	0.165	-0.32	0.753	1.16
Land ownership	0.006	0.008	0.77	0.444	1.14
Credit access	0.006	0.014	0.43	0.671	1.94
Training	0.017	0.136	1.23	0.221	1.90
Seredo variety	-0.041	0.016	-2.54	0.012**	2.21
Gadam variety	-0.045	0.035	-1.26	0.208	1.36
Serena variety	-0.034	0.018	-1.88	0.062*	1.34
Ochuti variety	-0.003	0.018	-0.14	0.887	1.87
Nyakabar variety	0.021	0.026	0.82	0.411	1.38
R-squared = 0.94					

Source: Own analysis (2019); ***Sig. 1%, **sig. 5% and *sig. 10%.

Heteroscedasticity and endogeneity test

The heteroscedasticity and endogeneity tests were done to check whether the OLS multiple regression model assumptions were violated. This study employed Breusch-Pagan and Koenker test to check for the presence of heteroscedasticity. The Breusch-Pagan test value (LM = 22.207; p = 0.052) and Koenker test value (LM = 11.955; p = 0.531) showed that there was no existence of heteroscedasticity. This was achieved after subjecting the outcome variable and some predictor variables to logarithmic transformation.

Endogeneity exists when the explanatory variable is correlated with the error term resulting to inconsistency and biasness of the parameter estimates of the model. Endogeneity could result from either error related to measurement of a variable or variable omission (Maddala and Lahiri, 1992). The results of endogeneity using Durbin and Wu-Hausman test yielded Durbin score (p = 0.7593) and Wu-Hausman score (p = 0.7733). Therefore, the null hypothesis for exogeneity was accepted, implying that the quantities of sorghum produced were exogenous.

Selected factors affecting sorghum productivity

Table 3 shows the relationship between the study explanatory variables and sorghum productivity. The model accounted for 94% variations in sorghum production (Table 3). Land size, labour, source of labour (hired labour), farm gate price, seredo seed variety and serena seed variety were found to have significant contribution to sorghum productivity. On the other hand, age, gender, household size, total monthly income, monthly off-farm income, market distance, credit access, training and other selected seed varieties had insignificant effect on sorghum productivity.

Land size had significant effect on sorghum productivity (p = 0.000, t = -13.67) at 1% level of significance. We found that there was inverse relationship between sorghum productivity and land size, that is, productivity reduced by a factor of 0.824 (Table 3) per one acre increase in land size. This negative relationship between farm size and productivity confirms the results of Hazell and Hangbladde (2010) and Birachi et al. (2013) that smaller farms tend to be more productive than larger farms. The reciprocal relationship between farm size and productivity can be ascribed to the fact that small farms are easily manageable to poor resource-constrained small-scale farmers. Increase in farm size is associated with increased input requirement and input use which might be unsustainable to most of the small-scale farmers. Significant effect of land size on productivity has also been reported from other studies (Obasi and Ukewuihe, 2013; Ayoola et al., 2016; Abdulrahman et al., 2018; Daudi and Omotayo, 2018) in contradiction to the findings of (Anyaegbunam et al., 2012).

On the other hand, labour in general, that is, irrespective of the source, was found to be significant and positively related with sorghum productivity (p = 0.006, t = 2.76) at 5% level of significance. An increase in man-day was found to increase productivity by a factor of 0.170 (Table 3). This is consistent with the findings of Katundu et al. (2014); Dessale (2018) and Ombuki (2018). In regard to the specificities of labour source, hired labour positively contributed to sorghum productivity (p = 0.053, t = 1.94) at 10% level of significance. This shows that an additional labour from hired labour source increases sorghum productivity by a factor of 0.035. A study in Europe on the productivity of labour reported that farms that relied on hired labour were more productive than those that purely used family labour (Kloss and Petrik, 2018). Conversely, in Bangladesh, family labour was found to be more productive than hired labour (Chowdhury, 2016). In addition, a study conducted in Malawi reported no significant effect of family labour offered by children on productivity whereas family labour offered by male and female adults negatively affected productivity (Assefa, 2010). The same study however, reported a significant and positive effect of hired labour on productivity, reflecting the findings of the current study. On contrary, family labour was insignificant and had a negative relationship with sorghum productivity. The inconsistencies in family and hired labour effect on productivity could be attributed to the differences in the socio-economic characteristics and geographical settings of the farmers. Alternatively, the positive effect of hired labour on productivity could be attributed to higher efficiency of hired labour than family labour.

Among the seed varieties used, seredo and serena varieties significantly contributed to sorghum productivity. Contrary to the expectation, a negative relationship was observed between these varieties and sorghum productivity. A decrease in productivity by a factor of 0.041 and 0.034 was observed as a result of using seredo and serena varieties respectively. The negative relationship between these varieties and sorghum productivity could be attributed to use of overstocked seeds, untimely planting, inadequate soil fertilization due to financial constraints and yield loss to birds all of which have adverse effect on the productivity of both local and new varieties. Low farm productivity in Siaya County has also been attributed to limited access to and use of certified seeds and fertilizer in the previous study (Obiero, 2013). This is consistent with the findings of this study, where only a smaller proportion of the farmers had adopted the use of improved sorghum varieties (Table 1). Similarly, Urassa (2017) highlighted limited access to improved seed varieties and fertilizer as a major constraint towards improving productivity. The productivity of sorghum has been adversely affected by birds. For instance, 60% grain loss to birds has been reported in eastern Kenya (Orr et al., 2013; Hiron et al., 2014). In addition, despite the use of improved sorghum seed varieties, a study conducted in three sorghum producing regions, namely; Machakos, Kitui and Makueni in Kenya reported a significant grain loss to birds. Approximately, 80, 51 and 14% yield loss to birds was reported in Machakos, Makueni and Kitui respectively (Mutisya et al., 2016). As a coping mechanism, most farmers in arid areas have prioritized drought tolerant local varieties over some new varieties which are less resistant to drought and birds (Amelework et al., 2016).

Farm gate price was significant (p = 0.000, t = 23.53) and positively related with sorghum productivity. We found that a unit increase in price was associated with 0.389 units increase in sorghum productivity. Output price influences farmers' adoption decision as well as resource allocation due to anticipated returns. Thus positive relationship between productivity and output price can be credited to increased resource allocation such as use of fertilizer which boosts sorghum's productivity. An interaction between the farm output price and the total factor productivity which interdependently affect farm profitability has been reported in the previous studies (Mugera et al., 2016).

Conclusion

The aim of this study was to analyze factors affecting sorghum productivity among small-scale farmers. Among the factors studied, land size under sorghum, labour, farm gate price and sorghum seed varieties used, that is, seredo and serena varieties were found to have significant effect on the overall sorghum productivity.

The study recommends that any policy intervention on sorghum production should prioritize the aforementioned significant factors. The study advises on the need for land redistribution as implicated by the inverse land size-productivity relationship. There is need for the county governments to provide machinery incentives such as tractors services at affordable hire charges to help during land preparation. This will reduce the cost of labour and the number of man hours required during land preparation. In order to achieve better prices for sorghum, the study emphasizes on the need to promote industrial use of sorghum, such as blending sorghum with other crops, for instance, sorghum-cassava floor. This will increase the industrial demand for sorghum and consequently better prices. This is likely to stimulate commercialization of sorghum production and make the crop competitive at the market. The seed varieties used, particularly serena and seredo varieties impacted on the overall productivity of sorghum. However, there was a negative relationship which could be accredited to limited use of improved sorghum seed varieties, over reliance on overstocked seeds extra. The study recommends increased support to farmers through regular provision of certified seeds and training to avert production constraints related to untimely planting, access to improved seed varieties and grain loss to birds.

Future research needs to lay focus on the marketing strategies adopted by the sorghum farmers and the associated transaction costs incurred across the various channels of marketing. This will help in designing policies targeted towards making sorghum enterprise more profitable. Further studies should also incorporate the effect of other factors such as spacing, fertilizer use, and pest and weed control on sorghum productivity at the farm level.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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