Scientific African 10 (2020) e00559

Contents lists available at ScienceDirect

Scientific African

journal homepage: www.elsevier.com/locate/sciaf

Analysis of the determinants of farmer participation in sorghum farming among small-scale farmers in Siaya County, Kenya

Samuel O. Okeyo[a,*], Samuel N. Ndirangu[a], Hezron N. Isaboke[a], Lucy K. Njeru[b], Jane A. Omenda[c]

[a] Department of Agricultural Economics and Extension, University of Embu, P.O.BOX 6-60100, Embu
[b] Department of Agricultural Economics, University of Nairobi
[c] Department of Land and Water Management, University of Embu

ARTICLE INFO

Article history:
Received 7 December 2019
Revised 29 August 2020
Accepted 16 September 2020

Key words:
Arid and semi-arid
Binary logistic
Production resource allocation
Sorghum adoption

ABSTRACT

Sorghum a**s** a drought tolerant crop provides an alternative opportunity towards increasing food production in the face of global climate change, mostly affecting Sub-Saharan Africa. Kenya is in the fore front in increasing the production of sorghum since its landmass is 80 percent arid and semi-arid. Few studies have evaluated farm and farmer related characteristics affecting adoption of sorghum production. Therefore, the objective of this study was to determine how selected factors affect the propensity of farmers to adopt sorghum production in Siaya County, Kenya. A total of 300 households were randomly selected as respondents in four sub-counties under sorghum production. Data was collected using semi-structured interview schedules administered to the selected farm households. The selected factors were subjected to descriptive analysis, while binary logistic regression model was applied for the quantitative analysis of the effect of these factors on adoption of sorghum production. The results of the regression analysis reveal that farm size, land size allocated to maize, beans and groundnut enterprise, land ownership and access to training significantly affected adoption of sorghum farming. The study underscores the significant impact of resource allocation decisions on uptake of sorghum production among farm households. Our findings show that farmers with larger farms are more likely to adopt sorghum production. However, due to industrial demand and food security potential of sorghum, we recommend that the extension service providers should also incentivize those with smaller farms to participate in sorghum production. Policies that will make sorghum enterprise more competitive over other crops, both at the farm and market level, are key. In addition, agricultural development policies should target provision of such services like training to streamline sorghum production in the arid and semi-arid areas in Kenya.

* Corresponding author.
E-mail address: sodhiambo14@gmail.com (S.O. Okeyo).

https://doi.org/10.1016/j.sciaf.2020.e00559

Introduction

It is has been projected that there will be 60 percent rise in the global food demand by 2050 and more so in the Sub-Saharan Africa (SSA) where the present cereal consumption largely depends on external imports [62]. This is likely to be exacerbated further by climate change since agriculture which is the main source of livelihood for most of the African households is entirely dependent on weather patterns. Approximately 97 percent of land under agricultural production is rain-fed, implying that the effect of climate change on crop production should be an issue of concern in SSA [51,52]. One of the entry point towards meeting sustainable agricultural production in SSA is matching crops with their suitable agro-ecological zones [53]. Thus, expanding the production, both in terms of output volume and area, of drought tolerant crops such as sorghum is relevant in SSA, which is 43 percent arid and semi-arid (ASALs) [24]. Significant increase in area under sorghum production will require proportionate increase in the number of farm households engaged in sorghum production. Thus, understanding the underpinning factors with respect to sorghum adoption among small-scale farmers in SSA is essential.

In Kenya, the country's economy hinges on agriculture which supports both the country's social and economic development. The agricultural sector directly contributes nearly 26 percent to country's total Gross Domestic Product (GDP) and indirectly an additional 27 percent through linkages with other related sectors such as manufacturing and service among others. Furthermore, 65 percent of the country's exports is derived from the agricultural sector, while at the same time, this sector employs nearly 60 percent of the population [40,65]. Despite, its contribution to the country's overall economic growth, the Kenyan agricultural sector is facing several challenges including declining soil fertility, unreliability and scarcity of rainfall, reduction in farm acreages, poor market infrastructure and credit inaccessibility among others [15]. This is even more pronounced among the small-scale farmers living in arid and semi-arid areas. Subsistence farmers who mostly rely on rain-fed farming are gradually being forced into more dryer and marginalized areas, thus making them more vulnerable to unpredictable weather patterns and droughts induced by climate change [15]. This production challenges are more evident in ASALs which constitute 84 percent of the Kenya's land mass [20]. The decline in agricultural productivity in Kenya has been aggregately caused by adverse climate change and socio-economic characteristics of farmers. Therefore, it means that the agricultural policies should promote production of crops adaptive to drought in the semi-arid areas of Kenya [45]. However, government policies and agricultural priorities have side lined these drought tolerant crops in favour of maize even in the arid areas that receive erratic rainfall. This is justifiable on the assertions of Njuguna et al. [48] that in Kenya, food security is measured on the basis of maize availability in the country. Nevertheless, there has been a successive decline in maize production in the country over the years resulting in food insecurity. Furthermore, the prices of maize and rice which are considered as major crops in Kenya, are on rise yearly, further impoverishing the poor [26]. Maize yields have also become unpredictable [32], thus, the need to promote alternative crops like sorghum which has the potential to cushion the farm households against risks.

The prevailing agricultural environment in Kenya created by existing policies and farmer characteristics may negatively impact on adoption as well as production of sorghum. For instance, in terms of land resource allocation, 85 percent of the Kenya's land under cultivation was devoted to beans and maize in the year 2015-2016. In addition, 83 percent of the Kenya's land mass is arid and semi-arid, and only 2 percent of cultivatable land is under irrigation [66]. Previous studies have demonstrated that there is a dearth of research based information on underutilized crops such as sorghum ([36,42]; Orr et al., 2016; [35,43]). Nonetheless, few studies have been conducted to assess what influences farmer participation in sorghum farming in Kenya despite the country being dominated by arid and semi-arid areas that make it suitable for sorghum farming. The existing studies on adoption of sorghum farming have limited documentation on how production resource allocation, land and labour in particular, among competing farm enterprises affect adoption of sorghum farming. Land and labour are among the key factors of production, thus farm decision making on how such factors are allocated and their availabilty may affect the uptake of various enterprises at the farm. Therefore, the objective of this study was to determine how selected factors affect the propensity of farmers to adopt sorghum production in Siaya County, Kenya.

Methodology

Study area

The research was conducted in Western Kenya, Siaya County. The County borders Kisumu County to the south-east, Vihiga and Kakamega counties to the north-east, Lake Victoria to the south and Busia County to the north. Siaya County lies between latitude $0^{0}26'$ to $0^{0}18'$ north and longitude $33^{0}58'$ east and $34^{0}33'$ west (Figure 1). Approximately 993 183 people live in the county [21]. Lower midland (LM) is the major agro-ecological zone in the area with slight traces of upper midland (UM) zones in high agriculturally productive zones [29]. Agro-ecological zones are divisions of land based on the environmental factors, production potential and land suitability [28]. The term "midland" refers to the suitability of a given zone to a particular crop or set of crops. For instance, lower midland (LM) zone is suitable for crops such as cotton, sorghum, sugarcane and groundnuts while upper midland (UM) zone for coffee [28]. The area receives mean annual rainfall of between 900 mm to 1500 mm with average temperature of 22.3 °C. The area is dominated with ferrasol soils which are low to moderately fertile. The major crops grown in the area include maize, beans, sorghum sweet potatoes among others [41].

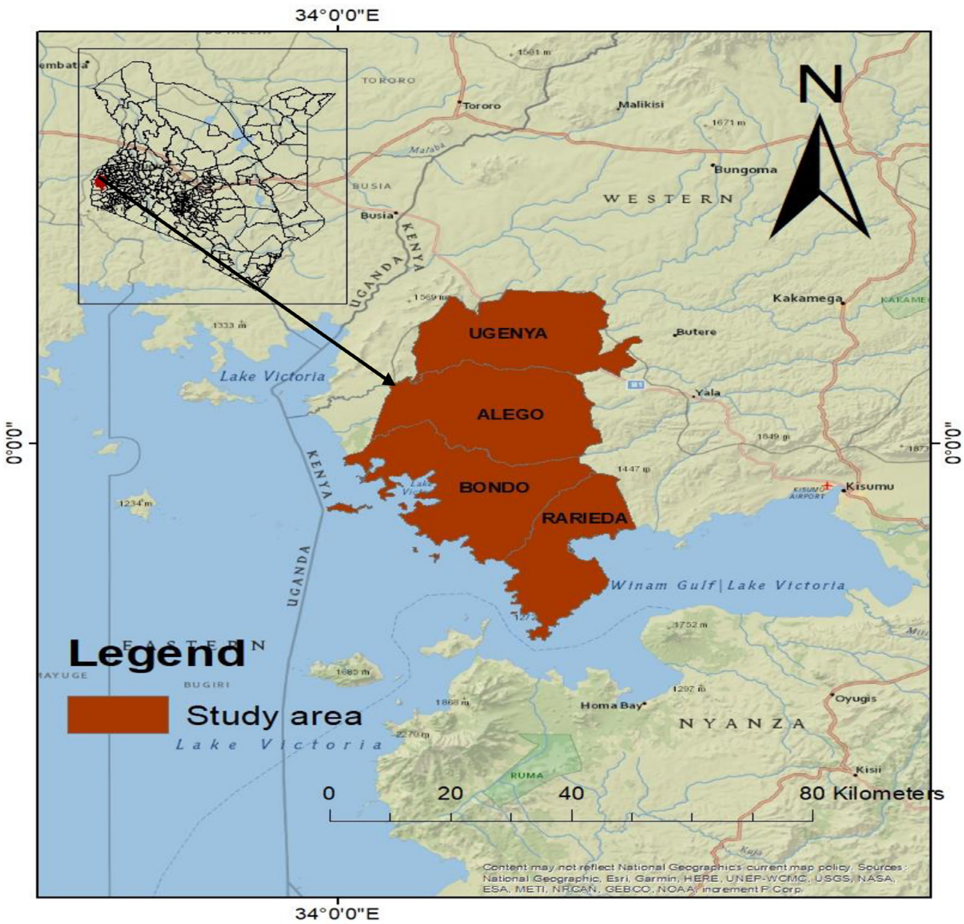

Figure 1. Map of Siaya County showing the study area

Table 1
Number of households selected for interview in each village

Region	Village	No. of households	Sample size	Percentage
Rarieda	Saradidi	98	39	13
Bondo	Onyatta	90	36	12
Alego	Uuna	185	73	24
Ugenya	Ramunde	383	152	51
Total		756	300	100

Data collection and sampling procedure

We used primary data collected from farmers in the study area. Stratified sampling was applied to select sub-counties, wards, villages and sample households. At the first stage, four sub-counties were purposively selected on the basis of sorghum production. In the second stage, a total of four wards, one ward per sub-county, were randomly selected. This was followed by a random selection of four villages, each from the wards selected. Finally, probability proportionate to size sampling technique was applied to select the required number of households for the interview from the villages, resulting to a total sample of 300 households (Table 1). Semi-structured interview schedules were used as tool of data collection during the survey. Before the main data collection exercise, reliability and validity of the interview schedules was assessed using 20 interview schedules administered to 20 randomly selected farmers. A reliability coefficient of 0.7 was achieved confirming that the instrument was adequately reliable. The items found to be important but inadequately captured in the interview schedule were re-modified to improve the validity of the interview schedules.

Theoretical framework

The decision of the farmer to adopt sorghum is informed by comparing the utilities derived from sorghum and other crops. Therefore, based on the concept of consumer utility maximization theory [16,17], farmers are assumed to adopt sorghum production with the expectation of deriving maximum utility which is constrained by the households' budget. The adoption decision of the farmer is therefore embedded on the anticipated utility derivable from sorghum enterprise. Profit and utility maximization goal is the major driver of resource allocation among farmers [25]. Since adoption exists as a dichotomous variable, that is adopter/non-adopter, econometric models such as binary logistics and probit models are applicable in analyzing such as an outcome variable. This study applied binary logistic model to analyze the factors affecting the probability of adopting sorghum production. Since, there is no assumption with regard to how the predictor variables are distributed, logistic regression is considered to be relatively flexible, easy to use and yield results which are easy to interpret [34]. The model also has no assumptions of linearity and heteroscedasticity.

The model was specified as shown [7];

$$P_i = F(Z_i) = 1/1 + e^{-(\alpha + \Sigma\beta_i X_i)} \tag{1}$$

Where, P_i is the probability of adoption of sorghum, X_i represents the ith explanatory variables, α and β_i are the parameters to be estimated and e is the base of natural logarithm. The equation can further be written in terms of odd ratios and the log of odds as;

$$\frac{P_i}{1 - P_i} = e_i^Z \tag{2}$$

$1 - P_i$ is the probability of household not adopting sorghum. Taking the natural log of the equation gives;

$$ln\left(\frac{P_i}{1 - P_i}\right) = Z_i = \alpha + \beta_1 X_1 + \beta_2 X_2 + \ldots \beta_n X_n + U_i \tag{3}$$

Where, U_i is the error term, randomly distributed,β_1, β_2... β_n are the parameters to be estimated while X_1, X_2 ... X_n are the explanatory variables [7]. Based on equation 3, we specified our model as;

$$Z_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \beta_{10} X_{10} + \beta_{11} X_{11} + \beta_{12} X_{12} + \beta_{13} X_{13} + \beta_{14} X_{14} + \beta_{15} X_{15} + \beta_{16} X_{16} + \beta_{17} X_{17} + U_i \tag{4}$$

Where, Z_i represents adoption of sorghum farming (dependent variable), X_1 to X_{17} represents gender (dummy), age of household head (years), education of household head (years), household size (number of household members), off-farm work (dummy), total size of cultivated farm (hectares), maize farm size (hectares), beans farm size (hectares), groundnuts farm size (hectares), labour used in maize (man days/hectares), labour used in beans (man days/hectares), labour used in groundnuts (man days/hectares), land ownership (dummy), extension contact (dummy), credit access (dummy), training (dummy), group membership (dummy) while β_0 to β_{17} are the parameters to be estimated and U_i is the error term.

Results and discussion

Study variables summary and expected effects

The selected variables for the study were summarized and presented in Table 2. Majority of the sampled households (66%) participated in sorghum farming. The mean age of the farmers was 46 which is comparable to the findings of several previous studies [11,18,39,57]; implying that farming is mostly dominated by the elderly. This is supported by the earlier assertions that the elderly concentrate on farming while the younger households concentrate more on off-farm employments to support livelihood [12]. Based on the previous findings, we hypothesize that age could have either positive or negative effect on adoption of sorghum farming (Table 2). For instance, according to Ayoola et al. [6], elderly farmers have low vigour for farming and hence could be viewed to have a lower chance of adopting sorghum production. Conversely, Demissie and Legesse [12] highlight that older farmers are more actively involved in farming activities than the younger ones who mainly opt for non-farm employments.

More female farmers (60%) than male farmers constituted the respondents. Studies have reported that subsistence farming is predominated by women [8,49]. In addition, it has been confirmed that men tend to dominate commercial farm enterprises while women produce in small plots for subsistence [10]. Similarly, Justus et al. [30] found that there were more female (65%) than male (35%) indigenous poultry farmers in Western Kenya. This further demonstrates that women dominate subsistence farm enterprises in the region to meet household food demand. Previous studies [5,18,38] have shown that gender has mixed effects on adoption decision. Therefore, we draw a priori expectation that gender could have either positive or negative effect on adoption of sorghum farming. The average period of schooling was 9 years with the majority of the sampled households constituting of 5 persons. This means that the majority of the households had attained some level of formal education and hence could easily adopt improved sorghum varieties. Educated farmers are able to critically analyze new practices as well as the benefits associated with these practices. Education was hypothesized to have a positive effect on adoption since it enhances awareness [37] and hence increases chances of adopting climate resilient crops such

Table 2
Descriptive results of variables and apriori effects on adoption of sorghum farming

Variable	Description	Mean	SD	Expected sign
Dependent variable				
Adoption of sorghum farming	1, if the respondent is participating in sorghum farming; 0, if otherwise	0.66	0.47	
Independent variable				
Age (years)	Age of the household head in years	46.10	13.80	+/-
Gender	1, if the gender of the respondent is male; 0, if otherwise	0.40	0.49	+/-
Education (years)	Number of years spent in school by respondent	9.40	4.10	+
Household size	Total number of household members directly dependent on household head	5.40	2.80	+
Off-farm work	1, if household has off-farm income source; 0, if otherwise	0.91	0.28	+/-
Farm size (hectares)	Cultivated total farm size in hectares	0.64	0.44	+
Maize farm size	Total farm size apportioned to maize	0.27	0.19	-
Beans farm size	Total farm size apportioned to beans	0.22	0.13	-
Groundnuts farm size	Total farm size apportioned to groundnuts	0.18	0.12	-
Labour maize (MD)	Labour used per hectare of maize	145.13	75.88	-
Labour beans (MD)	Labour used per hectare of beans	156.23	77.98	-
Labour groundnuts (MD)	Labour used per hectare of groundnuts	203.10	83.25	-
Extension service	1, if the household receives extension service; 0, if otherwise	0.40	0.50	+
Land ownership	1, if the land under cultivation is owned by the household; 0, if rented	0.92	0.27	+
Training	1, if the household receives training; 0, if otherwise	0.31	0.46	+
Credit access	1, if the household has access to credit; 0, if otherwise	0.25	0.44	+
Group membership	1, if the respondent is a member of any farmer group; 0, if otherwise	0.32	0.45	+

Note: SD is an abbreviation for standard deviation; MD denotes man days.

as sorghum. Educated farmers are also capable of searching and processing information and technologies relevant to their production challenges [4].

Large family sizes, as is the case in this study (5 members per household), indicate that households have readily available farm labour derived from the family. Akinola [3] posited that households utilize family labour as a copping strategy towards meeting high labour demand. Similarly, family labour helps the households to reduce the production cost incurred on hired labour [50]. Therefore, household size was assumed to have a positive effect on adoption of sorghum production. Most of the farmers (91%) had off-farm income sources. This shows that alongside agriculture, majority of the household heads depend on off-farm income for livelihood. Based on the literature, it plausible to draw a priori expectation that off-farm work can have mixed effects on farm production decisions. Su et al. [56] found that in China, income from off-farm employments improved households' capacity to invest in farm machineries. In contrast, Nasir & Hundie [47], reported that off-farm and farm activities compete for the scarce labour.

The mean farm size was 0.64 hectares which is reflective of the national average of 0.47 hectares owned by smallholder farmers in Kenya [14]. This means that most households own small parcels of land, thus are less likely to adopt multiple farm enterprises. Based on the other studies [11,13,18], we predict a positive effect of farm size on adoption of sorghum production. Households allocated an average land size of 0.27 hectares to maize, 0.22 hectares (beans) and 0.18 hectares (groundnuts), and was significantly different at 1% level of significance (Appendix). This shows that maize was allocated the largest proportion of land among other major crop enterprises that compete with sorghum in the study area. In regard to labour use, groundnut enterprise requires more labour per hectare compared to all other selected crop enterprises. Labour used per hectare of various crop enterprises was significantly different at 5% level of significance (Appendix). In Zambia, a significant decline was observed in the intensity of groundnuts production as a result of allocating more input to maize enterprise [68]. On the basis of this observation, we hypothesize that land and labour inputs used for the production of other crops will negatively affect adoption of sorghum farming.

Most of the households (60%) did not access extension service; implying paucity of such services in the study area. Similarly, 69% of the farmers did not receive training on improved varieties of sorghum. In regard to credit access, 75% of the sampled farmers reported lack of access to farm credit. Only 32% of the farmers had membership in farmer organized groups. This shows that there is limited access to institutional services meant to improve agricultural production in the area. Previous studies [19,30] have also cited paucity of institutional support services in the region. Institutional services enhance farmers' production capacity hence we assume that such services will have a positive effect on adoption of sorghum production. In terms of land ownership, 92% of the households cultivate owned parcels of land; implying that most households are able to adopt better farming systems and technologies due to high tenure security and absence of land rental fee. It has been established that farmers who own land are more likely to adopt multiple farm enterprises [5]. Therefore, land ownership was expected to have a positive effect on the likelihood of adopting sorghum production.

Comparison between sorghum adopters and non-adopters characteristics

The sample was stratified on the basis of sorghum adoption (adopters and non-adopters) and selected characteristics were determined for each stratum (Table 3). The mean age of the adopters (47) was significantly higher ($P<0.01$) than the mean age of non-adopters. Older farmers are more experienced [22,27] and as such are more likely to adopt technologies

Table 3
Comparison between sorghum adopters and non-adopters characteristics

	Adopters	Non-adopters		
Variable	Mean	Mean	Mean difference	t
Age in years	47.22	43.98	3.24	1.934*
Gender	0.39	0.43	-0.04	-8.110
Education in years	9.03	10.18	-1.15	-2.320**
Household size	5.88	5.19	0.69	2.074**
Off-farm income work	0.91	0.92	-0.01	-0.745
Total farm size	0.72	0.46	0.26	5.277***
Extension contact	0.49	0.24	0.25	4.506***
Training access	0.41	0.13	0.28	5.753***
Credit access	0.33	0.10	0.23	5.187***
Group membership	0.39	0.19	0.20	3.808***

*** Significant at 1%
** significant at 5%
* significant at 10%

related to sorghum production. In addition, sorghum enterprise requires relatively little inputs [49]. Therefore, resource constrained older farmers are more likely to participate in sorghum production to meet household food demand. This reflects the results of a study conducted in South Africa where majority of the sorghum farmers were aged between 50 - 60 years [8].

Majority of the farmers were literate as portrayed by mean years of schooling of 9 and 10 for adopters and non-adopters respectively that was significant at 5% level (Table 3). High literacy level implies the farmers are capable of adopting and applying improved production technologies which is likely to increase sorghum productivity in the area. Education facilitates awareness of the available improved practices and their benefits [33,37]. Therefore, highly educated farmers are more likely to adopt improved sorghum varieties to increase both output and farm income. Similarly, Khonje et al. [33], found that adopters of improved cassava varieties were more educated than the non-adopters.

In addition, the mean household size between the adopters and non-adopters was significantly different at 5% level of significance. The mean household size of adopters was higher than that of non-adopters. The large family sizes of sorghum adopters act as an additional source of farm labour thus facilitating uptake of multiple farm enterprises. In Kenya, it was observed that the number of farmers producing sorghum increases simultaneously as household size increases [49]. Further, larger household size exert more pressure on the available disposable income leaving little income for farm production. Therefore, such households may be compelled to produce sorghum since sorghum requires relatively less input investment [49]. The study revealed that sorghum farmers had larger farm sizes averaging 0.72 hectares compared to 0.46 hectares for non-sorghum farmers. The variations in farm sizes was significant at 5% level of significance (Table 3). With large farm size, farmers are able to diversify farming by participating in several farm enterprises. In addition, farm size is always perceived as a proxy for economic resource available to the farmer. Therefore, the propensity of adopting improved varieties is expected to increase concomitantly with the increase in this resource base [67]. Larger landholdings may also make it possible for farmers to pursue risk aversion strategies such adopting dry land crops such as sorghum alongside other major crops grown in the area. Correspondingly, Akinbode & Bamire [2] and Shiferaw et al. [54] found that adopters of improved varieties had larger farm size than non-adopters. Additionally, majority of the adopters (49%) had access to extension services, including training than the non-adopters. Extension services play a critical role in information and knowledge dissemination to farmers. According to Danso-abbeam et al. [11], extension agents provide farmers with information on both production and marketing. Therefore, farmers who have better access to extension services are more likely to adopt new or improved varieties to increase productivity [50].

In terms of credit access, 33% of the adopters had access to credit compared to 10% of the non-adopters. Access to credit enables farmers to purchase farm inputs [46], to acquire improved varieties and increase productivity [39]. Therefore, farmers who have access to inputs such as sorghum seeds have higher chances to adopt. Furthermore, 19% of non-adopters were in organized farmer groups which was lower than the 39% of the adopters (Table 3). Farmers tend to be more exposed to production information when in groups than when they work in isolation. In addition, farmer organizations facilitate positive behavior change among farmers towards new technologies [50]. In some cases, farmer organizations provide technical assistance and a platform for credit access to their members [63]. This partially explains why most farmers belonging to farmer groups are more likely to engage in sorghum production.

Factors affecting adoption of sorghum production

The results of binary logistic regression on factors affecting adoption of sorghum farming are presented in Table 4. Variance Inflation Factor (VIF) values greater than 10 indicate multicollinearity [23]. In this case, there was no multicollinearity problem since all the independent variables had VIF values of less than 10 (Table 4). The beta coefficients of the predictors were jointly significantly different from zero as indicated by Wald statistics (Chi^2, 112.34; p = 0.000). Hence, the null

Table 4
Binary regression results on selected factors affecting sorghum adoption

Variable	Coef.	Std. Err.	z	P>|z|	VIF
Gender	-0.0314	0.3225	-0.10	0.922	1.131
Age	0.0061	0.0112	0.54	0.589	1.138
Education	-0.0880	0.0438	-2.01	0.045**	1.193
Household size	0.0482	0.0628	0.77	0.442	1.106
Off-farm work	-0.3234	0.5433	-0.60	0.552	1.119
Farm size	2.8329	0.4742	5.97	0.000***	3.430
Maize farm size	-3.7133	0.7392	-5.02	0.000***	2.183
Beans farm size	-2.4551	1.0478	-2.34	0.019**	3.906
Groundnuts farm size	-3.8797	1.5986	-2.43	0.015**	4.360
Labour maize	0.0032	0.0178	0.18	0.856	1.039
Labour beans	0.0140	0.0215	0.65	0.516	3.740
Labour groundnuts	-0.0256	0.0257	-1.00	0.318	4.315
Extension contact	-0.0299	0.4301	-0.07	0.945	1.942
Land ownership	-0.2401	0.4444	-0.54	0.089*	1.049
Credit access	0.7574	0.5718	1.32	0.185	2.090
Training	0.9923	0.5715	1.74	0.083*	2.952
Group membership	-0.4126	0.5441	-0.76	0.448	2.650
Constant	0.6851	1.0530	0.65	0.515	
Number observations	300				
LR Chi^2 (17)	112.34				
Prob > Chi^2	0.000				
Percentage correctly predicted	84.70				

*** Significant at 1%
** significant at 5% & * significant at 10%

hypothesis that the beta coefficients of the predictor variable are jointly insignificant from zero was rejected. The model correctly predicted 84.70% of the total observations. The model summaries show that the selected model was best fit.

Formal education had a negative effect on adoption of sorghum farming. The negative β- coefficient of -0.088 associated with the years of formal schooling implies that a one year increase in formal schooling decreases the likelihood of adopting sorghum production by a factor of 0.088. This is attributable to the fact that majority of educated individuals often engage in off-farm employments that give better returns than farming. According to Awotide et al. (2016), educated farmers have high preference for secondary income sources which limits time spent on farming activities, and hence negatively affects adoption decisions. This corroborates the results of Awotide et al. (2016) but contradicts the findings of Wongnaa et al. [64] and Khonje et al. [33] who found a positive significant influence of education on adoption decision.

The total farm size owned by households significantly and positively affected adoption of sorghum farming. A one hectare increase in farm size increased farmer adoption of sorghum farming by a factor of 2.8329; implying that farmers with large farm sizes were nearly 3 times more likely to adopt sorghum farming than those with smaller parcels of land. Farmers who have larger farms are likely to adopt improved varieties of sorghum to maximize yield and profit. According to Danso-abbeam et al. [11], farm households with large landholdings usually engage in commercial farming and often adopt improved varieties for profit maximization. Large farm sizes also permit farmers to undertake several enterprises simultaneously ([49]; Boncinelli et al., 2008). Likewise, it has been reported that presence of larger cultivable land stimulates the households to try out new technologies in small-scale prior to actual adoption without risking the household food supply [67]. Positive effect of farm size on adoption has also been reported by previous studies [11,18]. In contrast, Wongnaa et al. [64] reported a negative significant influence of farm size on adoption of maize technologies. This was attributed to the inability of households to meet the high input demand usually associated with large farms.

The size of land allocated to maize had significant negative effect on farmers' participation in sorghum farming. The study found that the likelihood of farmers to adopt sorghum production reduces by a factor of 3.7133 when land size under maize increases by one hectare. Similarly, the size of land apportioned to beans enterprise negatively affected uptake of sorghum farming. Farm households producing beans were approximately 3 times less likely to adopt sorghum farming. We observed the same case under groundnuts enterprise in which per hectare increase in land size apportioned to groundnuts would reduce the probability of adopting sorghum farming by 3.8797 units. The possible explanation for this is that land becomes more limited as farmers tend to diversify farming activities. Since small-scale farmers own small parcels of land, adoption of sorghum farming in the presence of other already existing farm enterprises becomes untenable. According to Bowman and Zilberman [9], farmers' effort to diversify farming systems is often constrained by scarcity of inputs. Similar to our findings, Zulu et al. [68] reported a significant decrease in groundnuts uptake as a result of allocating more input to maize enterprise.

Furthermore, land ownership had a significant negative influence on the probability of adopting sorghum production. This means that farmers who own land are 2 times less likely to participate in sorghum production than those who cultivate rented lands. Farmers who cultivate rented farmlands are more likely to adopt improved varieties of sorghum to maximize yields and profit. Previous studies have demonstrated that adoption rates tend to be lower among farmers who own farmlands than those who produce in rented farmlands. This has been attributed to profit maximization focus since they are more likely to use improved seed varieties to increase productivity [31,55]. Land confers a sense of security to the farmers by eliminating uncertainty of land expropriation [58]. This may also have a negative impact on adoption of seasonal or short term crops such as sorghum in favour of long term farm investments. Our findings reflects the results of Kafle & Shah [31] and Sserunkuuma [55] but contradicts the findings of Theophilus et al. [59] and Awotide et al. [5].

Training on improved sorghum varieties positively contributed to adoption of sorghum farming among the farmers (Table 4). Access to training increased the propensity of a farmer to adopt sorghum production by a factor of 0.9923. This is attributable to knowledge gained through training and awareness on the benefits of sorghum farming by extension service providers. According to Tripp et al. [61], training widens the farmers' knowledge on production skills and techniques at the farm. In addition, in Vietnam, farmers who participate in training programs proved to be more knowledgeable on climate change and its impacts on agricultural production [60]. Therefore, it implies that through training, farmers are well informed on the production dynamics caused by climate change and are therefore more likely to be inclined to production systems such as those of dry land crops that thrive well in arid and semi-arid areas. This may positively influence farmers to adopt sorghum farming to enhance food security in their households. This concurs with the previous studies [1,44] that have also reported positive effect of training on adoption decisions.

Conclusions

The findings reveal that farm size under agricultural production and training on improved varieties had a positive effect on the likelihood of adopting sorghum production. On contrary, the years of schooling, the size of land allocated to maize, beans and groundnut enterprises, and land ownership negatively affected the propensity of adoption. The results show that farmers with larger landholdings have higher chances of adopting sorghum production. However, owing to industrial demand for sorghum, we recommend that the extension service providers should target even farmers with smaller farms in their attempt to promote sorghum production. The negative impact of other selected crop enterprises on the propensity of adoption suggests that most farmers are unable to meet the additional costs associated with farm diversification mostly due to capital constraint. Therefore, we recommend that there is need to support farmers, for instance, through provision of input subsidies. Furthermore, the results reveal that farmers who cultivate rented farmlands are more likely to adopt sorghum production, mainly because they have higher chances of adopting improved varieties to maximize yields and profit. This calls for a need to develop policies on land rental markets in Kenya to allow access to land for those who have none but can utilize it more productively. In addition, access to training positively contributes to participation in sorghum production. It is therefore recommended that the government should develop agricultural development policies that target creation of more extension institutions to support farmers through training on farm production related skills and technologies.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement

Samuel O. Okeyo: Investigation, Formal analysis, Writing - original draft. **Samuel N. Ndirangu:** Methodology, Writing - review & editing. **Hezron N. Isaboke:** Writing - review & editing. **Lucy K. Njeru:** Writing - review & editing. **Jane A. Omenda:** Writing - review & editing.

Acknowledgment

We acknowledge the University of Embu for funding the study. We are equally more grateful to the farmers for availing the useful information required during the research and the reviewers for enriching the article

Appendix

Table 5, Table 6

Table 5
Land size allocated to various competing crop enterprises

	Mean farm size (hectares)	SD	F	Sig.
Crop			9.520	0.000
Sorghum	0.30	0.23		
Maize	0.27	0.19		
Beans	0.22	0.13		
Groundnuts	0.18	0.12		

Table 6
Labour requirement among the competing crop enterprises

	Labour use/hectare	SD	F	Sig.
Crop			9.425	0.000
Sorghum	195.60	187.05		
Maize	145.13	75.88		
Beans	156.23	77.98		
Groundnuts	203.10	83.25		

Reference

[1] Abdoulaye, T., Abass, A., Maziya-Dixon, B., Tarawali, G., Okechukwu, R. U., Rusike, J., & Ayedun, B. (2014). Awareness and adoption of improved cassava varieties and processing technologies in Nigeria.
[2] W.O. Akinbode, A.S. Bamire, Determinants of adoption of improved maize varieties in Osun State, Nigeria, Journal of Agricultural Extension and Rural Development 7 (3) (2015) 65–72, doi:10.5897/JAERD2014.0605.
[3] B.D. Akinola, Risk preferences and coping strategies among poultry farmers in Abeokuta Metropolis, Nigeria, Global Journal of Science Frontier Research: D Agriculture and Veterinary 14 (5) (2014) 23–30.
[4] B.O. Asante, R.A. Villano, G.E. Battese, The effect of the adoption of yam mini-sett technology on the technical efficiency of yam farmers in the forest-savanna transition zone of Ghana, African Journal of Agricultural and Resource Economics 9 (311-2016-5576) (2014) 75–90.
[5] B.A. Awotide, T. Abdoulaye, A. Alene, V.M. Manyong, Assessing the extent and determinants of adoption of improved cassava varieties in south-western Nigeria, Journal of Development and Agricultural Economics 6 (162) (2014) 376–385.
[6] J.B. Ayoola, C.K. Dangbegnon, A. Daudu, T.M. Mando, I.Y. Kudi, J.O. Amapu, Ezui, Socio-economic factors influencing rice production among male and female farmers in Northern Guinea Savanna: lessons for promoting gender equity, Agriculture and Biology Journal of North America (2016) 2151–7517.
[7] A. Bogale, A. Shimelis, Household level determinants of food insecurity in rural areas of Dire Dawa, Eastern Ethiopia, African Journal of Food, Agriculture, Nutrition and Developmen 9 (9) (2009) 1684–5374.
[8] M.P. Botiabane, L. Zhou, I.B. Oluwatayo, F.O. Oyedokun, A.A. Oyelana, Socioeconomic Analysis and Technical Efficiency among Smallholder Sorghum Farmers in GaMasemola Township of Limpopo Province, South Africa, Journal of Economics and Behavioral Studies 9 (6 (J) (2017) 17–25.
[9] M.S. Bowman, D. Zilberman, Economic factors affecting diversified farming systems, Ecology and society 18 (1) (2013).
[10] S Curran, J Cook, Gender and Cropping: Sorghum in Sub-Saharan Africa, University of Washington, Washington, 2009.
[11] G. Danso-abbeam, J.A. Bosiako, D.S. Ehiakpor, F.N. Mabe, Adoption of improved maize variety among farm households in the northern region of Ghana, Cogent Economics & Finance 109 (1) (2017) 1–14.
[12] A. Demissie, B. Legesse, Determinants of income diversification among rural households : The case of smallholder farmers in Fedis district, Eastern hararghe zone, Ethiopia, Journal of Development and Agricultural Economics 5 (3) (2013) 120–128, doi:10.5897/JDAE12.104.
[13] L.N. Digal, S.G.P. Placencia, Factors Affecting the Adoption of Hybrid and High-Yielding Rice Varieties in the Philippines, Agricultural Research 9 (1) (2020) 1–8.
[14] FAO. (2015). Food and Agriculture Organization of the United Nations: The economic lives of smallholder farmers - An analysis based on household data from nine countries, Rome, 2015.
[15] FAO. (2017). Food and Agriculture Organization; Country Programming Framework for Kenya, 2014-2017.
[16] Feder, G., Just, R. E., & Zilberman, D. (1982). Adoption of agricultural innovation in developing countries: a survey.
[17] A.K.A. Ghadim, D.J. Pannell, A conceptual framework of adoption of an agricultural innovation, Agricultural economics 21 (2) (1999) 145–154.
[18] R.G. Ghimire, H.U. Wen-chi, R.B.S. Hrestha, Factors Affecting Adoption of Improved Rice Varieties among Rural Farm Households in Central Nepal, Rice Science 22 (1) (2015) 35–43.
[19] A. Gichangi, S.N. Maobe, D. Karanja, A. Getabu, C.N. Macharia, J.O. Ogecha, L. Kitonga, Assessment of production and marketing of climbing beans by smallholder farmers in Nyanza region, Kenya, World Journal of Agricultural Sciences 8 (3) (2012) 293–302.
[20] GoKNational Emerging Crop Policy, Government of Kenya, 2010.
[21] GoK. (2019). Kenya National Bureau of Statistics (KNBS). Statistical Abstract, 2019, Nairobi.
[22] P.P. Grabowski, J.M. Kerr, S. Haggblade, S. Kabwe, Determinants of adoption and disadoption of minimum tillage by cotton farmers in eastern Zambia, Agriculture, Ecosystems and Environment 231 (2016) 54–67, doi:10.1016/j.agee.2016.06.027.
[23] D. Gujarati, Basic econometrics, International edition, 3rd ed, McGraw Hill Book Co., New York, 2003.
[24] S.T. Hadebe, A.T. Modi, T. Mabhaudhi, Drought Tolerance and Water Use of Cereal Crops : A Focus on Sorghum as a Food Security Crop in Sub-Saharan Africa, Journal of Agro Crop Science 203 (2017) 177–191.
[25] H.G. Herath, J.B. Hardaker, J.R. Anderson, Choice of varieties by Sri Lanka rice farmers: comparing alternative decision models, American Journal of Agricultural Economics 64 (1) (1982) 87–93.
[26] H. Hoffler, B.O. Ochieng, High commodity prices - who gets the money? A case study on the impact of high food and factor prices on Kenyan farmers, Heinrich Boll Foundation, Berlin, Germany, 2009.
[27] K.Z. Islam, J. Sumelius, S. Backman, Do differences in technical efficiency explain the adoption rate of HYV rice? Evidence from Bangladesh, Agricultural Economics Review 13 (1) (2012) 93–104.
[28] Jaetzold, R., Schmidt, H., Hornetz, B., & Shisanya, C. (2006). Farm management handbook of Kenya Vol. II–Natural Conditions and Farm Management Information–2nd Edition part c; East Kenya Subpart C1 Eastern Province. Ministry of Agriculture, Nairobi, Kenya.
[29] Jaetzold, R., Schmidt, H., Hornetz, B., & Shisanya, C. (2009). Farm Management Handbook of Kenya, Vol. II: Nyanza Province, II, Sub - Part A.
[30] O. Justus, G. Owuor, B.O. Bebe, Management practices and challenges in smallholder indigenous chicken production in Western Kenya, Journal of Agriculture and Rural Development in the Tropics and Subtropics (JARTS) 114 (1) (2013) 51–58.
[31] B. Kafle, P. Shah, Adoption of improved potato varieties in Nepal: A case of Bara District, Journal of Agricultural Sciences–Sri Lanka 7 (1) (2012).

[32] S.J. Kebeney, B.M. Msanya, J.M.R. Semoka, W.K. Ngetich, A.K. Kipkoech, Socioeconomic Factors and Soil Fertility Management Practices Affecting Sorghum Production in Western Kenya : A Case Study of Busia County, American Journal of Experimental Agriculture 5 (1) (2015) 1–11.
[33] M. Khonje, J. Manda, A.D. Alene, M. Kassie, Analysis of adoption and impacts of improved maize varieties in eastern Zambia, World Development 66 (2015) 695–706.
[34] D. Liu, T. Li, D. Liang, Incorporating logistic regression to decision-theoretic rough sets for classifications, International Journal of Approximate Reasoning 55 (1 PART 2) (2014) 197–.
[35] T. Mabhaudhi, P.G.V. Chimoyo, A.T. Modi, Status of Underutilised Crops in South Africa : Opportunities for Developing Research Capacity, Sustainability 9 (9) (2017) 1569.
[36] T. Mabhaudhi, P. O'Reilly, S. Walker, S. Mwale, Opportunities for underutilised crops in Southern Africa's post-2015 development agenda, Sustainability 8 (4) (2016) 1–16.
[37] Mango, N., Makate, C., Tamene, L., Mponela, P., & Ndengu, G. (2017). Awareness and adoption of land, soil and water conservation practices in the Chinyanja Triangle, Southern Africa. International Soil and Water Conservation Research.
[38] M. Mariano, Jim, R. Villano, E. Fleming, Factors influencing farmers' adoption of modern rice technologies and good management practices in the Philippines, Agricultural Systems 110 (2012) 41–53, doi:10.1016/j.agsy.2012.03.010.
[39] F.E. Mmbando, L.J.S. Baiyegunhi, Socio-economic and Institutional Factors Influencing Adoption of Improved Maize Varieties in Hai District, Tanzania, Journal of Human Ecology 53 (1) (2016) 49–56.
[40] MoA (Ministry of Agriculture, (2012). Food Security Situation. Ministry of Agriculture, Government of Kenya.
[41] MoALF (Ministry of Agriculture, Livestock and Fisheries, (2016). Climate Risk Profile Siaya. Kenya County Climatic Risk Profile Series: The Kenya Ministry of Agriculture, Livestock and Fisheries, Nairobi, Kenya.
[42] Mukarumbwa, P., & Mushunje, A. (2010). Potential of sorghum and finger millet to enhance household food security in zimbabwe's semi-arid regions: A Review. Contributed Paper Presented at the Joint 3rd African Association of Agricultural Economists (AAAE) and 48th Agricultural Economists Association of South Africa (AEASA) Conference, Cape Town, South Africa, September 19-23.
[43] Mundia, C. W., Secchi, S., Akamani, K., & Wang, G. (2019). A Regional Comparison of Factors Affecting Global Sorghum Production : The Case of North America, Asia and Africa's Sahel.
[44] Murendo, C., Gwara, S., Mpofu, N., Pedzisa, T., Mazvimavi, K., & Chivenge, P. (2016). The adoption of a portfolio of sustainable agricultural practices by smallholder farmers in Zimbabwe.
[45] R. Mwadalu, M. Mwangi, The potential role of sorghum in enhancing food security in semi-arid eastern Kenya : A review, Journal of Applied Biosciences 71 (2013) 5786–5799.
[46] Mwambi, M., Oduol, J., Mshenga, P. M., & Mwanarusi, S. (2013). Does contract farming improve smallholder farmers' income? The case of avocado farming in Kenya (No. 309-2016-5293).
[47] M. Nasir, B. Hundie, The effect of off farm employment on agricultural production and productivity: Evidence from Gurage Zone of Southern Ethiopia, Journal of Economics and sustainable Development 5 (23) (2014) 85–98.
[48] I.M. Njuguna, C. Ng'endo, S.K. Makal, Influence of demographic characteristics on adoption of improved potato varieties by smallholder farmers in Mumberes Division, Baringo County, Kenya, Journal of Agricultural Extension and Rural Developmen 7 (4) (2015) 114–121.
[49] R.M. Ogeto, E. Cheruiyot, P. Mshenga, C.N. Onyari, Sorghum production for food security: A socio-economic analysis of sorghum production in Nakuru County, Kenya, Academic Journal 8 (47) (2013) 6055–6067.
[50] R.U. Onyeneke, Determinants of Adoption of Improved Technologies in Rice Production in Imo State, Nigeria, African Journal of Agricultural Research 12 (11) (2017) 888–896, doi:10.5897/AJAR2016.11737.
[51] J. Rockstrom, C. Folke, L. Gordon, N. Hatibu, G. Jewitt, F. Penning de Vries, R. Schulze, A watershed approach to upgrade rainfed agriculture in water scarce regions through Water System Innovations: An integrated research initiative on water for food and rural livelihoods in balance with ecosystem functions, Physics and Chemistry of the Earth 29 (15–18 SPEC.ISS.) (2004) 1109–1118.
[52] Salahuddin, M., Gow, J., & Vink, N. (2020). Effects of environmental quality on agricultural productivity in sub Saharan African countries: A second generation panel based empirical assessment. Science of The Total Environment, 140520.
[53] Sebastian, K. (2009). Agro-ecological zones of Africa. International Food Policy Research Institute: Washington, DC, USA.
[54] B. Shiferaw, M. Kassie, M. Jaleta, C. Yirga, Adoption of improved wheat varieties and impacts on household food security in Ethiopia, Food Policy 44 (2014) 272–284, doi:10.1016/j.foodpol.2013.09.01.
[55] D. Sserunkuuma, The Adoption and Impact of Improved Maize and Land Management Technologies in Uganda, Journal of Agricultural and Development Economics 2 (1) (2005) 67–84.
[56] W. Su, T. Eriksson, L. Zhang, Y. Bai, Off-farm employment and time allocation in on-farm work in rural China from gender perspective, China Economic Review 41 (2016) 34–45.
[57] M. Suvedi, R. Ghimire, M. Kaplowitz, Farmers' participation in extension programs and technology adoption in rural Nepal : a logistic regression analysis, Journal of Agricultural Education and Extension 23 (4) (2017) 351–371.
[58] Tenaw, S., Islam, K. Z., & Parviainen, T. (2009). Effects of land tenure and property rights on agricultural productivity in Ethiopia, Namibia and Bangladesh. University of Helsinki, Helsinki.
[59] K.A. Theophilus, A. Robert, S. Paul, Determinants of the extent of adoption of maize production technologies in Northern Ghana, African Journal of Agricultural Research 14 (19) (2019) 819–827.
[60] T.Q. Trinh, R.F. Rañola Jr, L.D. Camacho, E. Simelton, Determinants of farmers' adaptation to climate change in agricultural production in the central region of Vietnam, Land Use Policy 70 (2018) 224–231.
[61] R. Tripp, M. Wijeratne, V.H. Piyadasa, What should we expect from farmer field schools? A Sri Lanka case study, World Development 33 (10) (2005) 1705–1720.
[62] M.K. Van Ittersum, L.G.J. van Bussel, J. Wolf, P. Grassini, J. van Wart, N. Guilpart, K.G. Cassman, Can sub-Saharan Africa feed itself? Proceedings of the National Academy of Sciences 113 (52) (2016).
[63] M. Wollni, D.R. Lee, J.E. Thies, Conservation agriculture, organic marketing, and collective action in the Honduran hillsides, Agricultural economics 41 (3-4) (2010) 373–384.
[64] C.A. Wongnaa, D. Awunyo-Vitor, J.E.A. Bakang, Factors affecting adoption of Maize production technologies: A study in Ghana, Journal of Agricultural Sciences-Sri Lanka 13 (1) (2018) 81–99.
[65] World Bank GroupKenya Economic Update; Policy options to advance the Big 4, World Bank, Nairobi, 2018 Retrieved from: https://openknowledge.worldbank.org/handle/10986/29676 .
[66] World Bank. (2019). Unbundling the Slack in Private Sector Investment. Transforming Agriculture Sector productivity and Linkages to Poverty Reduction.
[67] N.G. Wubeneh, J.H. Sanders, Farm-level adoption of sorghum technologies in Tigray, Ethiopia, Agricultural systems 91 (1-2) (2006) 122–134.
[68] P. Zulu, T. Kalinda, G. Tembo, Effects of the Maize Input Subsidy Program on Groundnuts Production in Zambia, Journal of Agricultural Science 6 (7) (2014) 253–264, doi:10.5539/jas.v6n7p253.