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Research Article

The Role of Sorghum in Enhancing Food Security Among Smallholder Farmers in Makueni County, Kenya

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Abstract

In the wake of climate change and prevailing food insecurity, there has been increased attention on crops that can withstand harsh climatic conditions and have the potential to sustain livelihoods. Sorghum (*Sorghum bicolor)* is among the cereal crops with the potential to address these unprecedented challenges. It grows in arid and semi-arid regions characterized by unpredictable weather patterns, rising poverty levels, and food insecurity. In Kenya, sorghum ranks third in terms of production and importance. Nevertheless, there is prevailing food insecurity in Makueni County, where sorghum thrives well. Hence, the purpose of this study was to assess the role of sorghum in enhancing food security among smallholder farmers by establishing the potential factors influencing sorghum production and income from sorghum. A multistage sampling method was used to select a sample of 96 respondents. Data analysis involved the use of multiple linear regression model and gross margin analysis. The results indicated that experience, household size, and extension service influence sorghum production positively, while distance to all-weather roads and off-farm income have a negative effect. Gross margin results revealed sorghum is a profitable enterprise with an average net farm income of about 10,760 KES per acre. This suggests that sorghum production improves the income of sorghum-producing households and consequently enhances food security. The study, therefore, proposes strategies such as developing appropriate training facilities and strengthening extension services to boost sorghum production and thus promote food security among smallholder farmers. Furthermore, national and county governments should develop efficient road networks and provide incentives to sorghum producers to enhance access to services and markets, and foster specialization in sorghum enterprise.

Keywords

Gross Margin Analysis, Food Security, Multiple Linear Regression, Sorghum

1. Introduction

Amid growing food insecurity and climate change, there has been increased attention towards crops with the ability to withstand harsh climatic conditions and sustain livelihoods. Sorghum (*Sorghum bicolor*) is among the major cereal crops identified to address these unprecedented challenges [1]. It grows in marginalized arid and semi-arid areas characterized by frequent crop failure, unreliable rainfall, and rising poverty levels [2]. Therefore, sorghum is among the pathways with the

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potential to address challenges of food insecurity, climate change, low agricultural productivity, and failing conventional food systems.

Sorghum is an important cereal crop grown primarily for food and fodder, and ranks fifth globally after maize, wheat, rice, and barley in terms of area and production [3]. The crop is majorly grown in developing countries, particularly in Africa, Asia, and Latin America, and serves over 750 million people residing in ASALs regions. Moreover, Africa is the largest sorghum producer, accounting for about one-third of the total global production. This dominance is possibly due to the prevalence of tropical weather conditions in Africa, which provides a suitable environment for sorghum production. However, global sorghum yield remains relatively low compared to other cereal crops such as wheat, maize, and rice, with average yield ranging between 2.5 and 5t/ha [4].

In the recent past, sorghum production has widely been promoted in SSA as a food security crop due to its ability to withstand harsh climatic conditions and the constant failure of other staple crops. For instance, in Kenya, maize is the most preferred and commonly grown crop by smallholder farmers. However, due to unreliable rainfall and unpredictable weather patterns in the country, the crop has lost its former glory among farmers due to its consistent failure. As a result, there have been concerted efforts and interest towards sorghum in ASALs. To promote sorghum production, initiatives such as developing high-hybrid sorghum varieties have been carried out by Kenya Agricultural Research Institute (KARI). In addition, various projects that support farmers to produce or adopt new sorghum varieties have been implemented by the government and its partners to foster food security and improve household incomes in rural areas. These projects include; the Eastern Province Horticulture project, the Orphan Crops project (2003-2007), and the Traditional Food Crops project. The main purpose of these initiatives was to promote the adoption of new sorghum varieties and as well improve the sorghum yields, and ultimately boost food security in the ASALs regions.

In Kenya, sorghum is a traditional crop, mainly grown by small-scale farmers for subsistence purposes due to its strong ability to adopt abiotic and biotic stress and low input requirements [5, 6]. It ranks third after maize and wheat [7]. The crop thrives well in Eastern, Western, and Coastal regions of the country. Sorghum is a multifunctional crop with benefits ranging from its role as a source of nutritious food, animal feed, and raw material in industrial processing [8, 9]. As a source of nutritious food, sorghum grain contains high levels of carbohydrates, fiber, vitamins, antioxidants, and anti-inflammatory properties [10, 11]. Additionally, the grain is used to manufacture bread and porridge [12]. In terms of industrial purposes, sorghum is used to produce wax, edible oils, and alcoholic beverages [9]. Besides, sorghum is a viable source of fodder [13]. Hence, sorghum is a viable crop for food and feed insecure households, and provides a great opportunity for income generation, particularly for rural communities in sub-Saharan Africa (SSA).

Despite the numerous benefits of sorghum and consistent efforts to improve sorghum production, the yield of the crop remains low in Kenya, with an average yield ranging between 0.7 and1 ton per hectare [14], which is far below the potential yield of between 2 to 5t/ha. Besides, sorghum production continues to show inconsistent trends in Kenya (Figure 1), reaching the highest level in 2020 and lowest in 2022.

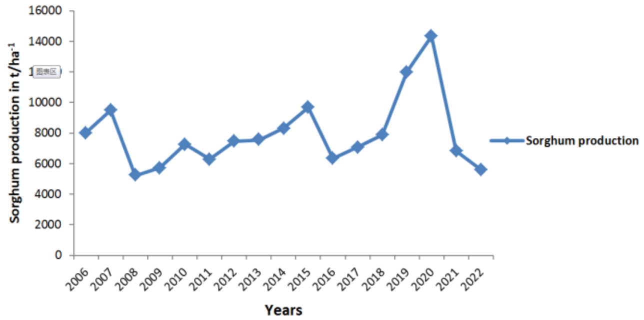

Figure 1. *Trends of sorghum production in Kenya from 2006 to 2022 (FAOSTAT, 2014).*

Makueni County is among the leading producers of sorghum in Kenya [9]. However, food insecurity and high poverty levels remain major challenges in the county with about 40% of the population being food insecure. Additionally, sorghum production in Makueni County is far below its potential. Further, there exists scarce empirical evidence regarding the role of sorghum in enhancing the food security of smallholder farmers in Makueni County. Therefore, this study sought to fill in this knowledge gap. The study is beneficial to farmers, policymakers, and other relevant stakeholders as it provides strategies that can be employed to improve sorghum production and income of households. Ultimately, it will enhance household food self-sufficiency and improve the living standards of poor households in Makueni County, thus boosting national food security.

2. Material and Methods

2.1. Description of Study Area

The study was conducted in Makueni County, Kenya. The County is located in the Eastern part of Kenya and borders Kitui County to the East, Taita Taveta County to the South, Kajiado County to the West, and Machakos County to the North [15]. The County is characterized by rapid population growth (approx. 921, 168) and arid and semi-arid climatic conditions [16, 17]. Therefore, the County presents a suitable context for our study since it hosts the majority of smallholder sorghum farmers and is characterized by arid and semi-arid climatic conditions. Sorghum is among the main crops grown in the County. Figure 2 presents the map of Makueni County, Kenya.

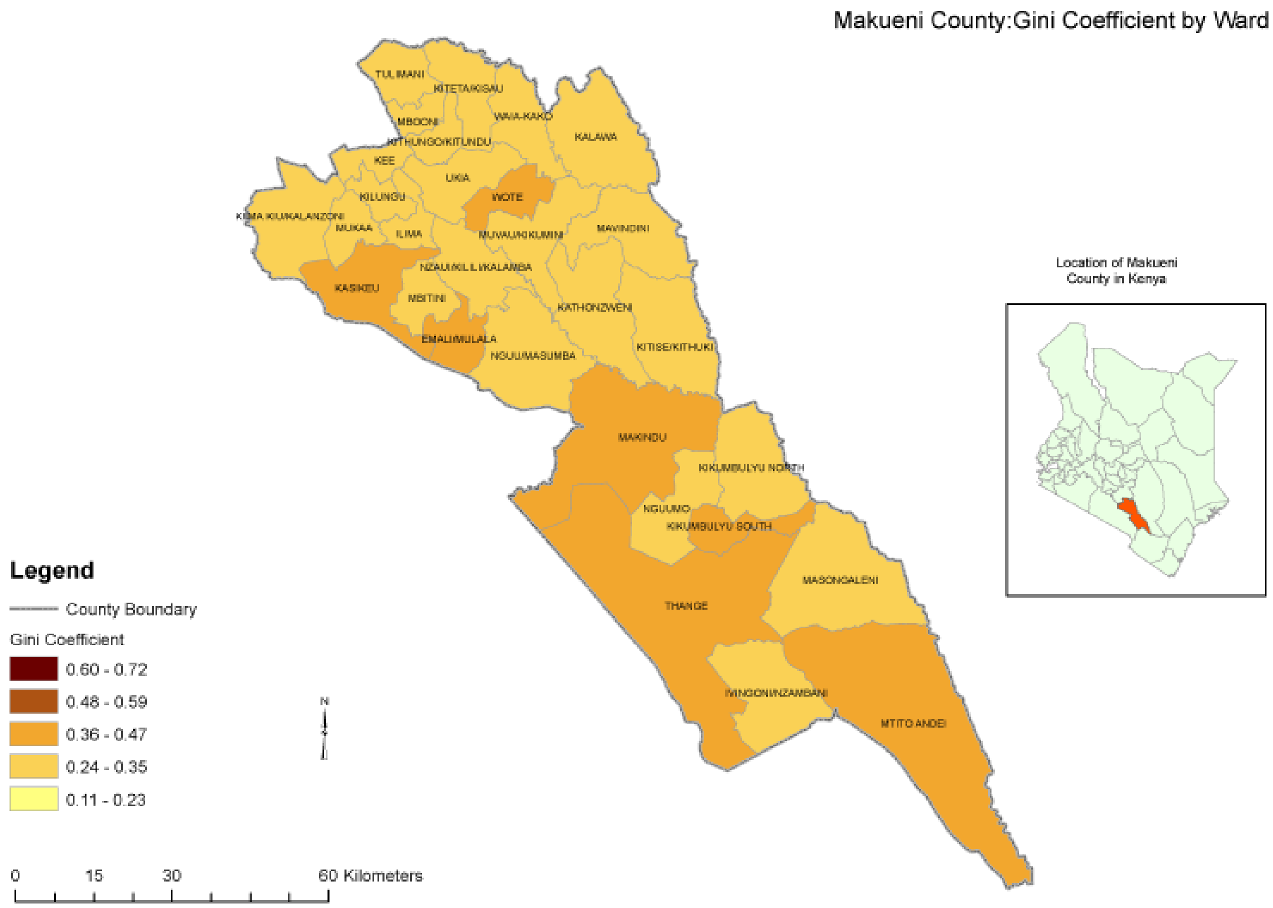

Figure 2. Map of Makueni County.

2.2. Sampling and Data Collection

The study adopted a cross-sectional survey design to obtain the data from respondents. The data was collected between January 2023 and February 2023. According to the Kenya Bureau of Statistics (2016), Makueni County hosts approximately 150,000 smallholder farmers. Hence, our target population for this study was smallholder farmers in Makueni County.

A multistage sampling procedure was used in data collection. The first stage involved the purposive selection of three sub-counties, where sorghum production is more profound (Makueni, Kibwezi West, and Kibwezi East). This was followed by a purposive selection of one ward from each sub-county (Kathonzweni, Makindu, and Mtindo Andei). In the third stage, households were sampled systematically, from a list of sorghum-producing households. The list was developed with the help of the extension officer at the ward level. This procedure yielded a sample size of 96 households.

Following the Kothari [18] formulae (equation (1)), the sample size was determined as follows;

$$n = \frac{z^2 pqN}{e^2(N-1) + z^2 pq} = \frac{(1.96)^2 0.5*0.5(150000)}{(0.1)^2(150000-1)+1.96*0.5*0.5)} = 96 \quad (1)$$

Where; n represents the sample size for a finite population, N is the size of the population, p represents the frequency of the estimated n (p=0.5 for developing population) while, p+q=1, and e is the marginal error (considered to be 10% in the study) and z shows the normal reduced variable at 0.05 level of significance which is equivalent to 1.96.

A structured questionnaire was developed and used for data collection. Before actual data collection, the tool was pretested to establish its validity and relevance to the study. After establishing its suitability, the questionnaire was administered to the respondents by trained enumerators. The data obtained was on socio-economic characteristics, institutional factors, and farm attributes (sorghum production inputs, outputs, and sales). Additionally, two focus group discussions from each ward consisting of eight to ten participants were conducted to generate an in-depth understanding of sorghum production.

2.3. Analytical Model

The data was analyzed using descriptive statistics and multiple linear regression. Descriptive statistics such as means and percentages were used to summarize the socio-economic characteristics of the smallholder sorghum farmers while a multiple linear regression model was used to establish the factors influencing sorghum production. Furthermore, gross margin analysis was carried out to estimate the effect of sorghum production on the smallholder farmers' income in the study area.

2.3.1. Factors Influencing Sorghum Production

A multiple linear regression (MLR) model was applied to assess factors influencing sorghum production. The model was suitable since estimates the relationship between independent variables and a continuous dependent variable [19]. Additionally, the model is regarded as a superior statistical tool due to its relative simplicity in checking the model assumptions such as variance, linearity, and outlier effects [20].

In the study, the model was specified as follows;

$$Y = \beta_1 + \beta_2 X_2 + \beta_3 X_3 +, \dots, +B_n X_n + \varepsilon \quad (2)$$

Where; Y= is a dependent variable estimated as the quantity of sorghum in kilogram per acre, $\beta_1$represents the intercept, $\beta_2 \dots \beta_n$ are the parameters to be estimated, and $X_2 \dots X_n$ are the independent variables hypothesized to affect sorghum production while ε represents the disturbance term. Table 1 presents the variables used in the model, their measurements, and the hypothesized effect.

Table 1. *Description of variables hypothesized to influence sorghum production.*

Variable	Variable description and units	Hypothesized effect
Gender	Gender of the respondent; 1= male; 0=Female	+, -
Age	Age of the respondent in years	+, -
Household size	Number of household members	+
Education level	Number of years spent in formal education	+, -
Experience	Number of years in sorghum production	+
Farm size	Total area under sorghum in acres	+
Extension service	Access to extension service; 1 = Yes; 0 = No	+
Credit	Access to credit: 1 = Yes; 0 = No	+
Membership in social groups	1= Member of a group; 0 = Not a member	+
Distant to all-weather roads	Distance in Kilometres	-
Distant to the market	Distance to the market in Kilometres	-
Off-farm income	Average annual income from other sources (KES)	+, -

Note: KES= Kenyan Shilling.

A diagnostic test for statistical problems such as heteroscedasticity and multicollinearity tests was conducted to investigate whether the assumptions of the MLR model were met and to establish the suitability of the data set. Breuch-Pagan and Koenker tests were carried out to check the presence of heteroscedasticity. The result yielded a Breuch-Pagan value of 21.117 with a p-value of 0.042 while the Koenker test value was 10.795 with a p-value of 0.541, indicating the absence of heteroscedasticity.

Likewise, a Variance Inflation Factor (VIF) test was computed to rule out the possibility of serious multicollinearity between the independent variables in the MLR model. Conventionally, VIF<5 indicates the absence of significant multicollinearity [21]. A mean VIF value of 1.76, with individual VIF ranging between 1.02 and 2.19 was reported in the study, suggesting the absence of significant multicollinearity between the variables. Hence, the variables in Table 1 qualified for inclusion in the MLR model.

2.3.2. Effect of Sorghum Production on the Income of Smallholder Farmers

Gross margin has been used substantially in the literature to evaluate the economic performance of the firms [22-24]. It is among the oldest, most accurate, and simplest tools used in farm management analysis [25]. Gross margin is computed as the difference between gross farm income (GFI) and Total Variable Cost (TVC) [26].

In this study, gross margin was used to assess the effect of sorghum production on the income of farmers due to its ability to evaluate the economic performance of the enterprises. Additionally, the tool was suitable since it serves as an indicator of enterprise feasibility and its potential to contribute to household income [27]. Conventionally, gross margin is computed per cropping season or annum.

The Gross margin was given as;

$$GM = TR - TVC \quad (3)$$

Where; GM represents gross return per acre, TRis the total revenue per acre (computed as a total output in kilograms multiplied by unit price), while TVC represents total variable cost per acre (expressed as the total value of inputs used in sorghum production) in the proceeding season.

3. Results and Discussion

3.1. Socioeconomic Characteristics of the Respondent

Table 2 presents the findings of socioeconomic characteristics of the smallholder sorghum farmers. The results indicate that the farmers involved in sorghum production are relatively old, with an average mean of 52 years. These results reveal that sorghum production is predominantly undertaken by the elderly. This finding corroborated those of Okeyo et al. [19], which indicated that sorghum production is an economic activity of older people.

Table 2. Descriptive statistics of smallholder sorghum farmers.

Continuous variables (n=96)	Mean	Std Dev.	Min	Max
Age	52.0	7.88	26.0	78.0
Household size	6.3	1.98	2.0	13.0
Experience	7.32	3.21	2.0	14.0
Education level (years)	8.03	4.12	0.0	16.0
Cultivated land under sorghum (acres)	1.8	1.38	0.25	4.0
Distance to market (km)	3.0	2.57	0.7	8.0
Distance to all-weather roads (km)	1.9	1.09	0.2	2.0
Off-farm income	28,549	17,691	7,880	75,550
Categorical variables	Percentage (%)	Std. Dev.	Min	Max
Gender: 0=female;1 otherwise	72.5	.47	0	1
Marital status: 1= married; 0 otherwise	85.4	.10	0	1
Access to extension service	20.0	.21	0	1
Access to credit	18.0	.49	0	1
Membership in social groups	65.0	.22	0	1

Note: KES= Kenya Shilling, km= Kilometers.1 USD = 110 KES at the time of the survey.
Source; Field survey 2023

The majority of sorghum farmers in the study areas had a relatively high number of members within their households (6). Additionally, the results indicate a low literacy level among sorghum producers with the majority attaining primary education level. This finding was possibly attributed to a lack of or inadequate schools in rural areas [28]. Thus, hindering farmers' access to formal education in the study areas. The finding was in tandem with those from the baseline survey conducted by Muui et al. [9], which showed low literacy levels among sorghum farmers in the Eastern region of Kenya.

Furthermore, the study revealed that the respondents had attained a moderate average experience of seven years in sorghum production. Since the majority of respondents were illiterate, the knowledge on sorghum on sorghum production was probably derived from hands-on experience. Similarly, the households allocated an average land size of about 1.8 acres to sorghum, suggesting that the allocation to sorghum production is relatively low. This finding shows that sorghum production is primarily subsistence. In terms of proximity, the average distance to all-weather roads and the nearest market was found to be three (3) kilometers and 1.9 kilometers respectively. Additionally, the average annual income from off-farm activities was KES 28, 549, implying that a good proportion of farmers relied on other income-generating activities alongside sorghum enterprise.

The results (Table 2) indicate that sorghum production is dominated by women. This finding reveals that both women and men participate in sorghum production. However, there is a high involvement of women (72.5%) compared to men (27.5%). Therefore, there is a need to sensitize men on the role of the sorghum in livelihoods. This finding is comparable to the previous studies by [9, 29], which indicated that sorghum production is predominantly undertaken by women. However, it contradicts empirical evidence that suggests sorghum production is male-dominated [9, 30]. In terms of group membership and access to credit, about 65% and 18% of the farmers belonged to a group and had received credit facilities respectively. In regards to extension service, approximately 20% of the sampled respondents received extension service.

3.2. Factors Influencing Sorghum Production

Table 3 presents the results of the multiple linear regression model. The model accounted for about 95% of the total variance in sorghum production, with an R^2 value of 0.95. The F value of 39.6 significant at 1% was obtained, indicating the overall goodness of fit of the MLR model. The results show that experience, household size, farm size, and access to extension service influence sorghum production positively and significantly while distance to all-weather roads and off-farm income affects sorghum production negatively.

Experience in sorghum production ($p<0.05$) was found to be a positive and significant factor influencing sorghum production. The finding suggests that, as years of sorghum production increased by one, *ceteris paribus*, yield from sorghum improved by about 0.467 kilograms per acre. This finding was possibly due to the assertion that experienced farmers are better equipped with skills and information regarding new technologies of production that may help to produce at the optimal level. Similarly, household size was found to influence sorghum production positively and significantly ($p<0.05$), indicating that an increase in household membership, increased sorghum production by 5.2%. Household is a major source of farm labor, particularly in small-scale agriculture. Therefore, a household with a high number of individuals participating in sorghum production is expected to be more productive. This finding corroborates those of Idrisa et al. [31], who noted that household membership plays a key role in production as it provides human labor and the necessary skills required for crop production.

Table 3. *Estimated regression parameter results on factors influencing sorghum production.*

Variable	Coefficient	Std error	P-value
Gender	-.084	.157	.593
Age	-.016	.014	.246
Experience	.467**	.015	.036
Household size	.052**	.046	.026
Education level	.042	.022	.248
Farm size	.073***	.085	.000
Extension service	.643*	.175	.054
Distance to all weather road	-.238**	.116	.041
Distance to market	-.069	.156	.658
Acess to Credit	.021	.268	.937
Membership in social groups	-.283	.281	.313
Off-farm income	-.536***	.278	.001
Constant	1.264	.522	.062
Model summary			
R Squared	0.952		
F-stat	39.60***		

Note: *, **, and *** denotes significance levels at 10%, 5%, and 1%, respectively.

The results further indicate that the proportion of land under sorghum positively affects sorghum production ($p<0.001$) among the smallholder farmers. A positive relationship was expected since farmland is a key factor of production. Hence, farmers with large land allocated for sorghum production are expected to earn more returns from sorghum enterprises. This finding was in line with those of Ogeto et al. [29], which indicated that farm size affects sorghum production significantly. Likewise, access to extension service was positively correlated ($p<0.1$) with sorghum production. A one percent increase in extension service increased sorghum production by 0.643%, *ceteris paribus*. This result resonates well with those from Hassan & Nhemachena [32] who revealed that access to extension services enhances the ability of the farmers to learn and acquire the recommended information regarding the new and existing techniques used in production.

The results (Table 3) further show that distance to all-weather roads is inversely correlated ($p<0.05$) with sorghum production, implying that an increase in distance of farmers' land from all-weather roads by one kilometer decreases the sorghum output by 0.238 kilograms per acre, *ceteris paribus*. The finding is consistent with those of Ogada et al. [33] who found that as the farmland gets closer to all-weather roads, farmers may have better access to transport facilities and support from the other relevant stakeholders regarding seed multiplication, new technologies, new markets, etc., and hence improve their productivity levels as compared to when they are far away from the weather roads. Besides, if the distance to all-weather roads is too great, the transaction and transport costs are likely to be high, leading to an increase in input costs, which ultimately affects sorghum production.

Off-farm income was found to influence sorghum production negatively. This finding suggests that as income from non-farm activities increased, sorghum output declined and vice versa, especially if the income from non-farm activities was not invested directly into sorghum production. A negative association can possibly be explained by the fact that as off-farm income increases, farmers may tend to ignore and neglect sorghum production and concentrate on other off-farm income-generating activities. Ultimately, impacting sorghum production negatively. Also, off-farm activities may draw labor away from sorghum enterprise, which in turn can lead to labor constrained, consequently affecting sorghum production negatively.

3.3. Effect of Sorghum Production on the Income of Smallholder Sorghum Farmers

Gross margin was used to establish the effect of sorghum production on the income of smallholder farmers as indicated in Table 4. The result revealed an average net farm income (NFI) of 10, 760 KES per acre of sorghum production. This indicates that sorghum production is a viable and profitable economic enterprise with the potential to promote food security and sustain livelihoods.

Table 4. *Average gross margin of sorghum production (kg/acre) in the preceding season of production*.

Variables	Average quantity/acre	Unit price (KES)	Value
1. Gross Returns			
(a)Average yield(kg)	410kg	40	16,400
2. Inputs			
(i)Variable inputs			
(a)Seeds(kg)	4kg	520@2kg	1,040
(b)fertilizer(kg) Urea	50kg	2500@50kg	2,500
(c)chemicals(litre)	-	-	-
(d)hired labour(man/day)	6 persons	350@person	2,100
3. Total inputs cost			5,640
4. Net Farm Income(NFI) (1-3)			10,760

Note: KES denotes Kenya Shilling, 1 USD= 110 KES at the time of the survey. Source; Field survey, 2023

4. Conclusion and Recommendation

The paper assessed the role of sorghum in enhancing food security by evaluating the factors influencing sorghum production and the effect of sorghum production on the income of smallholder farmers. Multiple linear regression model and gross margin analysis were applied for data analysis respectively. The results indicated that experience, household size, farm size, and access to extension service influenced sorghum production positively and significantly while distance to all-weather roads and off-farm income were found to affect sorghum production negatively.

Further, gross margin analysis revealed that sorghum production is a viable and profitable economic enterprise with a net farm income of 10, 760 KES per acre. Based on the findings, the study concludes that sorghum plays an important role in enhancing the food security of smallholder farmers and has the potential to sustain livelihoods.

In line with major findings, the study, recommends the following; first, there is a need to develop training facilities and strengthen extension services that boost sorghum production and enhance food security among smallholder farmers. Second, national and county governments should develop efficient road networks to enhance access to services, inputs, and markets and thus improve sorghum production and reduce food insecurity among smallholder farmers. Similarly, policymakers should put in place supportive agricultural policies that enhance sorghum production and encourage smallholder farmers to specialize in producing sorghum, especially in arid and semi-arid areas of Kenya like Makueni County to ensure food availability, accessibility, and stability in these regions.

Lastly, information regarding input and output markets should be made available to the smallholder farmers to enable them to access the markets effectively.

Abbreviations

KES	Kenya Shilling
USD	United State Dollar
GMA	Gross Margin Analysis
NFI	Net Farm Income
MLR	Multiple Linear Regression

Author Contributions

Kinyili Mutua: Conceptualization, Methodology, Formal analysis, Data curation, Writing the original draft, writing review-editing

Jane Mwaura: Methodology, writing review-editing

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Data Availability Statement

The data will be made available upon request.

Conflicts of Interest

The authors declare no conflicts interests.

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