Analysis of the Factors Affecting Farm-Level Output of Mangoes among Small-Scale Farmers in Machakos County, Kenya

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Abstract

The study examined the factors affecting farm-level output of mangoes among small-scale farmers in Machakos County, Kenya. Data was obtained from a sample of 352 small-scale mango farmers that were proportionately selected from six wards of the study area. A structured interview schedule was used for data collection. Both descriptive and inferential statistics were employed in data analysis. The stochastic Cobb-Douglas production function results indicated that active family and hired labour, pesticides, and manure were the inputs that influenced mango output with 0.463 return to scale. This indicates a decreasing return to scale of mango output in the study area. In addition, household size, mango farming income, farm size, amount of credit, and extension contacts were the factors that had a positive effect on mango farm-level output, while cost of pesticides and cost of manure precipitated a negative effect. The study recommends to the Ministry of Agriculture in collaboration with County Government to strengthen the extension contact between farmers and agricultural extension agents by making frequent visits to mango farmers and organizing training programs to encourage them to apply good management practices for improved production. Furthermore, small-scale mango farmers access to functional input markets will enhance farm-level mango output.

Keywords: *Mango, farm-level output, Cobb-Douglas production*

Introduction

Mango is the second most important fruit in the tropics and subtropics after banana. It is commercially grown in more than 90 countries worldwide and consumed in both fresh and processed forms (Mujuka et al., 2020). Globally, India is the largest producer of mango, accounting for 50% of the total output. Kenya is among the leading producers of mangoes in Africa (United States Agency for International Development, 2018). Mango production targets fresh fruit markets and the processing industry. Additionally, its fruit flavor and high nutritional value have placed it in a higher popular position as a source of income to farmers, traders, and international markets (Bundi et al., 2020).

Diversification into horticultural produce is becoming more attractive to small-scale rural farmers across the globe. This is because the worldwide production of fruits has grown faster compared to cereal crops and the total value of the horticultural crops traded at present is more than double that of cereals (Mariyono, 2020). As a result of this, farmers involved in horticultural production usually earn much higher farm incomes as compared to cereal producers, and their per capita income is also five times higher than cereal producers (Ayalew, 2015). Mango tree has been classified as a permanent horticultural crop which means it occupied the field for a long period and does not have to be replanted for several years after each harvest (Horticultural Crop Directorate, 2018). Despite this, its potential has not been fully exploited due to constraints such as pest and diseases, poor agronomic practices and glut during peak seasons.

In Kenya, the area under mango cultivation has been increasing over the years to 46,364 hectares in 2017 and 49,098 hectares in 2018 respectively (Horticultural Crop Directorate, 2018). Statistics show that mango cultivation contributes approximately 5% of the Agricultural Gross Domestic Products (GDP) and 2% of the national GDP, employing a considerable number of the seasonal labour force (Ministry of Agriculture Livestock and Fisheries, 2018). Kenya is dominated by two type of mango varieties the local and the exotic or improved (Githiomi et al., 2019). The latter are usually grafted on local mangoes and are grown for consumption and processing. Most of the local varieties tends to have high fibre content and this characteristic make its unpopular for processing. In addition, the local varieties are left to grow naturally without much of the crop husbandry. Research on mango production in Kenya has concentrated much on varietal introduction of high yielding varieties which have different qualities that are suitable for either fresh consumption and processing (Gichungi et al., 2020). Despite the adoption of these mango varieties by small-scale farmers the farm-level output has been declining (MoALF, 2018) and the factors leading to this remains unknown.

Mango farming is faced by numerous challeges ranging from lack of clean planting materials, poor agronomic practices to price fluctuations which in turn leads to low level of mango output hence leading to food insecurity and low income for the small-scale farmers.

In Machakos County, the ecological conditions form an essential prerequisite for good growth and development of mango tree, however the potential for this crop is under-utilized with only 5,593 hectares (Ha) under mango production (MoALF, 2018). However, the County experiences lack of improved mango technologies, inadequate processing technologies and unreliable supplies. Hence production of mangoes for domestic consumption and market supply is low. Further, this problem has resulted from small-scale farmers relying on the local mango varieties which are of small sizes, highly perishable and have higher fibre content (MoALF, 2018). Therefore, failure to address these problems will lead to loss of livelihoods, enhanced poverty and food insecurity in the area. It is against this background that, the study focuses on the factors that affect farm-level output of mangoes among small-scale farmers in Machakos County.

Methodology

The study was carried out in Machakos County, Kenya. The County is located on latitude 0°45′S and longitude 36°45′E. It is bounded in the West, North, East, South, South West and North West by Nairobi and Kiambu, Embu, Kitui, Makueni, Kajiado, Muranga, and Kirinyaga respectively. The County covers an area of 6,208km^2 and has a population of 1,421,932 (Kenya Bureau of Statistics, 2019). In addition, the study area receives a bimodal rainfall pattern, with the long rains experienced in March to May, while short rains are received between October and November. The average annual rainfall ranges between 500 to 1300 mm per annum and temperatures range between 18°C -25.7°C (Government of Kenya, 2018). These conditions are suitable for mango farming.

The study employed two-stage stratified sampling to collect data from 352 mango-farming households in Machakos County. Firstly, the six major mango producing wards in the County (Mbiuni, Makutano/Mwala, Masii, Muthetheni, Wamunyu, and Kibauni) were purposively selected. Secondly, a location was randomly selected from each of the six wards. Further, a Sub-location was selected from each location and finally, a village was randomly selected from each Sub-location. To obtain the number of mango-farming households to be interviewed in each village probability proportionate to size technique was applied. In this case, the total number of mango-farming households in each village was divided by the total number of households in the selected villages then multiplied by the sample size. The interval between the households to be interviewed was estimated by dividing the total number of households in the village by the required number of mango-farming households.

This study applied Production theory to explain the quantitative relationship between the selected factors and the level of mango output. In economics, this theory explains the technical relationship between the physical inputs and output. It describes the laws of proportion, represents the technology of the firm, and includes all the technically efficient methods of production. According Daniel and Afofum, (2019), a production function expresses a functional relationship between quantities of inputs and outputs. It shows how and to what extent output changes with variation in inputs during a specified period. The general production equation adopted was as shown in (equation 1).

$Y = f(x_1, x_2, x_3 \dots x_n)$……………………………………………………….....…....1

Where Y represents mango output, x_1 is land, x_2 is labour x_3 is the amount of capital used in production and x_n represents other factors that influence the farm output. The production function shows the maximum amount of mango produced using alternative combinations of land, labour, and capital. Output Y is also the total physical product (TPP). The marginal physical product (MPP) of an input is the additional output produced by employing one more unit of that input while holding all other inputs constant. The log linearized Cobb-Douglas production function was applied in this study to express this production relationship. This model was most suitable for this study because it provides parameters that are easy to estimate and interpret. The model was expressed in the form shown below;

$Y = f(X) = AX_1\beta_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4, \beta_1 \dots \beta_4 > 0$…………………………….…….2

Where Y is the quantity of mangoes produced (kgs); X_1 is the active family labour (man-days), X_2 is hired labour (man-days), X_3 is the amount of manure applied (kgs) and X_4 is the amount of pesticides applied (litres).

Considering the natural logarithm of the above equation, the production function was expressed as;

$\ln Y = A + \beta_1 \ln X_1 + \beta_2 lnX_2 + \beta_3 lnX_3 + \beta_4 lnX_4 + \varepsilon$…………………………………..…..3

Apart from the above measurable inputs used in mango production, there were other factors that influenced the amount of output obtained and were included in the model and presented as;

$\ln Y = \ln \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 \dots + \beta_n \ln X_n + \alpha_1 z_1 + \cdots \alpha_1 z_n + \varepsilon$ ……………..………4

Where Y is the mango output, β_0 is the vertical intercept, X_1 to X_n are quantities of inputs used. β_1 to β_n are the inputs co-efficient of the regressor or multiplier that describes the size of the effect the inputs have on the dependent variable Y. α_1 is the coefficient for socio-economic and institutional factors and z_1 to z_n are the socio-economic and institutional factors. ln is natural logarithm and ε is the composite error term.

Results and Discussion

Farm and Farmers Characteristics of the Sampled Respondents

The descriptive statistics demonstrated that the majority (73%) of the respondents were male farmers. This implies that the male-headed households in the study area dominate in mango farming. In addition, the mean age of the respondents was 57.82 years indicating that elderly people involved more in mango farming activity compared to the youths who engage in other off-farm activities. The results also indicated an average household size of six members. On average, the sampled household head years of schooling (education) was 10 years. Education empowers a farmer to make informed decisions on production, marketing, and identify value addition opportunities where they exist.

The mean number of years spent in mango farming (farming experience) was 16.66 years. This indicates that most of the farmers had engaged in the farming of mangoes for many years and thus they had a good experience in mango farming. The mean of the total land size owned by the respondents was 2.5 hectares. In addition, the average farm size under mango farming was 1.29 hectares, which implies there is room for expansion of the mango enterprise.

The mean household income among the mango farmers was KES 25599.43 per month. Moreover, the average number of extension contacts between extension officers and mango farmers was 2.0 visits per year. This indicates that farmers in the study area received information regarding mango production and market supply. The average amount of mango produced by the farmers in the study area was 3011.20 kilograms per harvesting season. The results further indicate that the apple variety was predominantly (80%) grown by small-scale farmers in the study area, followed by Tommy variety (56%), Kent variety (29%), and Vandyke variety with 10%.

Table 1: Selected Farm and Farmers' Characteristics of the Sampled Farmers

Variables	Mean	Std. Dev
Gender (1=male, 0=female)	0.73	0.02

Age (years)	57.82	11.65
Household size	6.0	1.65
Education (years)	10.00	2.29
Farming experience(yrs)	16.66	9.09
Total farm size (hectares)	1.29	0.55
Household income (KES)	25599.43	25547.15
Extension contact (visits)	2.0	1.20
Quantity produced (kgs)	3011.20	1833.50
Mango varieties (Yes)		
Apple	0.80	0.12
Tommy	0.56	0.47
Kent	0.29	0.46
Van dyke	0.10	0.30

Maximum Likelihood Estimates of Stochastic Cobb-Douglas Regression Analysis

The Cobb-Douglas production function was estimated using the maximum likelihood estimation procedure in STATA software version 13. The outcome of the analysis is presented in Table 2. The sum of the β coefficients ($\sum_{i-1}^{4} \beta_i$) indicates the return to scale of a given production function (Martinho, 2017). A summation of β coefficients that is less than one ($\sum_{i-1}^{4} \beta_i < 1$), indicates decreasing returns to scale (DRS), while summation equal to one ($\sum_{i-1}^{4} \beta_i = 1$) indicates constant return to scale (CRS) and that greater than one ($\sum_{i-1}^{4} \beta_i > 1$) indicates an increasing return to scale (IRS). The sum of the estimated parameters of inputs used in mango production was found to be 0.463 which is less than one (Table 2), implying that mango output was found to be less than the proportion at which the inputs are increased (decreasing return to scale)

The results also indicate that a value of sigma squared (σ^2) which denotes the goodness of fit and correctness of the distributional form assumed for the composite error term which had a value of 0.0600 and was significant at 1% level. The value of Log-likelihood and that of Wald chi-square show that the specified model fits stochastic frontier estimation. Further, a lambda (λ) value of 6.4092 was significantly different from zero, thus indicating deviations between actual and predicted mango output in the study area resulted from differences in production and management practices and not random variations.

Results in Table 2, shows the effects of inputs on mango output. The estimated parameters in the production function expressed positive coefficients. This implies that if more inputs were applied in equitable proportions, mango production would increase by the total value of associated coefficients. In terms of inputs used in mango production, the results revealed that active family labour and hired labour had a significant influence on the amount of mango produced. This can be explained by the fact that mango production is a labour intensive activity and requires extensive management practices such as pruning, spraying as well as harvesting and this requires available and active labour. These findings are consistent with Dessale, (2018) that active family labour and hired labour were the key inputs that significantly influenced amount of farm output obtained by the farmers. In addition, labour was found to positively influence agricultural output among small-scale farmers (Kloss and Petrick, 2018; Ombuki, 2018).

The amount of pesticide and manure applied had a positive and significant influence on mango production. The results of the study show that one-unit increase in the amount of pesticide and manure increases the amount of output by 0.1818 and 0.0684 units respectively. Mango farmers in the study area apply farmyard manure to improve soil fertility, which in turn leads to improved quality and production while pesticides help to control fruit-fly pest, which is destructive to mango fruits. This study agrees with the findings by Ntakayo et al. (2016) that the amount of pesticides and organic fertilizer (manure) applied influence apple and mango output among small-scale farmers respectively.

Table 2: The results of the effects of inputs on mango output

Variables (inputs)	Parameter	Coef.	Std. Err.	Z	P-value
Constant	β_0	6.8241	0.1331	1.2800	0.0000
Ln family labour(man-day)	β_1	0.1272	0.0650	1.9600	0.0500**
Ln hired labour(man-day)	β_2	0.0860	0.0390	2.2100	0.0270**
Ln pesticides(litres)	β_3	0.1818	0.0236	7.6900	0.0000***
Ln manure (Kgs)	β_4	0.0684	0.0118	5.7900	0.0000***
Log-likelihood		-221.3531			
Wald chi2(4)		276.1900			
Lambda		6.4092	0.0403	158.8800	0.0000
Sigma squared σ^2		0.0600			0.0000

(***, ** shows significant variables at 1% and 5%, respectively); Ln = natural logarithm.

Factors Affecting Mango Production among Small-scale Farmers

Results in Table 3 shows the effects of selected socio-economic and institutional factors on mango farm-level output. The table gives statistical parameters that indicate various aspects of the analyzed data. These parameters include the alpha (α) coefficients, p-values (levels of significance), and the Variance Inflation Factor (VIF). The α coefficients show the effects that given changes in the independent variables would have on the dependent variable. Multicollinearity test was done after model estimation. Multicollinearity problem occurs due to a linear relationship among the independent variables and therefore the separate effect of the independent variables on the dependent variables becomes difficult to identify because of the strong relationship between them (Martinho, 2017). Multicollinearity exists when the Variance Inflation Factor (VIF) of an independent variable exceeds 10 or less than one, none of the independent variables had VIF values less than 1 or greater than 10, implying that there was no Multicollinearity problem (Table 3). The R-squared was 0.862 implying that the independent variables explained about 86% of the total variations in the mango output with the remaining 14% been due to uncontrollable factors in the model.

An increase in household size by one-person increases mango output by 0.3875 units. The plausible explanation is that mango production is a labour intensive activity and the size of the household determines labour required to undertake mango production and management activities, which in turn increases the level of output. These findings concur with Abubakar and Sule, (2019) results that one of the factors influencing the level of production and productivity of small-scale farmers is the household size. This contradicts results by Muyanga and Jayne, (2019) that large household size brings competition of resource and results to sub-division of land resulting to small-sizes allocated for crops this in turn reduces the amount of agricultural output.

Mango farming income was positive and significant at 1% level of significance. This indicates that an increase of mango income by one unit increases mango output by 0.1851 units. The plausible explanation is that income from mango farming determines the farmer's ability to access important resources and inputs such as manure, pesticides, and payments for labour, which are the key factors in agricultural production. These findings are in line with Alam et al. (2017) that income from mango farming had a significant influence on production among small-scale farmers.

An increase in farm size by one hectare increases mango output by 0.9170 units. The credible explanation for this is that mango farmers in the study area allocated land to mango farming considering it as an income generating enterprise. Due to this farmers considered mango to be an important commercial crop and were interested in increasing land under mango production to create room for more improved varieties thus increasing the level of output. These results are in line with Alam et al. (2017) results that land allocated to mango farming (farm size) had a significant influence on the level of mango output among small-scale farmers. In contrary, previous studies have argued that smaller farms are more efficient than larger ones resulting to inverse relationship between farm size and production (Desiere, 2016; Daudi and Omotayo, 2018). This is because small farms are easily manageable by the poor resource-constrained small-scale farmers. However, this is not applicable to permanent fruit trees like mangoes that occupy large space thus farmers require huge piece of land in order to increase the number of trees and thus increased yield.

The amount of credit used by the farmer had a positive influence on mango production at 1% level of significance. The positive α coefficient shows that an increase in the amount of credit accessed by one unit increases mango output by 0.1191units. This can be attributed to the fact that credit is critical in financing of inputs such as manure, fertilizers, pesticides, and herbicides hence increasing the chances of high production. Similarly, access to farm credits was among the essential factors needed for agricultural production, and with it, farmers were able to secure farm inputs such as; farm equipment, fertilizer, and hired labour thus increasing the level of agricultural output among small-scale farmers (Mohammed et al., 2016; Udoka et al., 2016).

As expected, the cost of pesticides had a negative influence on mango output. An increase in the cost of pesticides by one unit reduced the amount of mango output by 0.1818units. The study found that the cost of pestcides was higher than what farmers can afford to buy and this lead to massive destruction of the fruits by fruit-fly pest thus leading to reduced level of production. Findings by Mrema, (2017) was that an increase in cost of pesticides and herbicides reduces production among small-scale farmers. The cost of manure was found to have a negative significant influence on mango production. An increase in the cost of manure by one unit reduces the amount of mango output by a factor of 0.0934. Information obtained from farmers who did not keep livestock was that, the cost of manure was higher and thus they could not afford and this had side negative effect on soil fertility leading to decreased yield. These results are in line with findings by Tun et al. (2020) that an increase in the cost of manure reduces the amount of agricultural output in the dry zone of Myanmar.

The extension contact positively influenced mango output at 1% level of significance. The positive α coefficient indicates that an increase in the extension contact increases mango output by 0.4726 units. The positive impact signifies that effective and efficient extension contact between farmers and extension officers is very crucial in agricultural production as it determines how efficient improved production practices will be delivered to the farmers within their location and how these practices shall be adopted by the targeted farmers. Contrary to these findings Ntakayo et al. (2016) established that the number of extension visits had no significant influence on apple production among small-scale farmers. The reason behind this was that farmers did not approprately apply techniques delivered by extension agents such as use of improved production technologies such as pruning and spraying among others

Table 3: Factors affecting mango farm-level output among small-scale farmers

Variables	Parameter	Coef.	Std. Err	Z	P-value	VIF
Gender(1=male,0=female)	α_1	-0.0748	0.0809	-0.9200	0.3550	1.09
Household age(yrs.)	α_2	0.5410	0.3386	1.6000	0.1100	4.13
Household size	α_3	0.3875	0.1807	2.1400	0.0320**	2.29
Level of education (yrs.)	α_4	0.3161	0.2329	1.3600	0.1750	3.05
Mango farming income(KES)	α_5	0.1851	0.0639	2.9000	0.0040***	1.04
Annual household income	α_6	0.0625	0.0301	2.0700	0.0780	1.53
Farm size (Ha)	α_7	0.9170	0.1664	5.5100	0.0000***	2.15
Amount of credit used (KES)	α_8	0.1191	0.0405	2.9400	0.0030***	1.24
Cost of pesticides(KES)	α_9	-0.1888	0.0607	-3.1100	0.0020***	5.95
Cost of manure(KES)	α_{10}	-0.0934	0.0333	-2.8000	0.0050***	6.07
Extension contact(visits)	α_{11}	0.4726	0.0911	5.1900	0.0000***	1.05
Constant	α_0	-5.5208	1.8275	-3.0200	0.0030	

(***, ** show significant variables at 1% and 5% levels); Prob>F=0.0000; R-squared=0.862; Mean VIF=2.69

Conclusions and Recommendations

The study concludes that, active family, hired labour, pesticides, and manure were the inputs that influenced mango output with a 0.463 return to scale. Further, household size, mango farming income, farm size, amount of credit, and extension contacts were the factors that exhibited a positive effect on mango production among small-scale farmers, while the cost of pesticides and cost of manure precipitated a negative effect on mango production. The area of land allocated to mango enterprise by small-scale farmers determines the number of trees owned and this reflects the level of output. Extension contact between the farmers and extension officers is vital as it determines how efficient improved mango production practices will be delivered to the farmers within their location and how these practices shall be adopted by the targeted farmers.

This study recommends to the Ministry of Agriculture in collaboration with the County Government and other private sectors to strengthen the extension contact between farmers and agricultural extension agents by making frequent visits to mango farmers and organizing training programs to encourage them to apply good management practices for improved production. Furthermore, small-scale mango farmers access to functional input markets will enhance farm-level mango output.

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