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Effects of recommended improved crop technologies and socio-economic factors on coffee profitability among smallholder farmers in Embu County, Kenya

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This study was carried out to determine the combined effects of recommended production technologies and farmer characteristics on coffee profitability at the farm level in Embu County, Kenya, using the profit function approach. Data were collected using semi structured questionnaires from a sample of 376 farmers who were randomly selected from six cooperative societies, using multistage stratified and probability proportional to size sampling techniques. Primary data on level of adoption of production technologies, level of usage of farm inputs, factor prices, coffee output and farmer demographics were collected. The data were entered in Excel sheets for initial analysis and tabulation then coded for primary analysis of the combined effect using the Profit function model. The results revealed that adoption of the recommended coffee varieties and rate of manure application were positive and significant in affecting coffee profitability at 5% level of significance. However, capping of coffee stems (bearing heads) had a significant negative effect on coffee profitability. Other factors that were found to have a significant negative influence on coffee profitability were the price of manure and foliar fertilizer. Surprisingly, increasing the wage rate had a significant positive influence on coffee profitability. These results portrayed that there is potential of increasing coffee profitability in the study area through adoption of the improved coffee varieties and recommended rates of manure as well as stabilizing factor prices of key inputs. In addition, paying a higher wage rate would act as an incentive and motivation for increased productivity hence increased coffee net returns.

Key words: Input, coffee variety, manure rate, capping, marginal product, marginal value product, Profit function.

INTRODUCTION

Kenya's economy is predominantly anchored in agriculture. One of the goals of the Kenyan Vision 2030 for the agricultural sector is to achieve an average growth rate of 7% per year (GoK, 2012). The agricultural sector contributes 51% of Gross Domestic Product (GDP) directly and indirectly, accounts for 65% of Kenya's total exports, 18% of formal employment and over 60% of informal employment in rural areas (GoK, 2012). Industrial crops contribute 55% of Kenyan agricultural exports, implying that a decline in productivity of these crops would mean reduced gross domestic product (GDP) and economic growth. Coffee, *Coffea arabica* is Kenya's fourth leading foreign exchange earner after tourism, tea, and horticulture (MoA, 2011). The 2016-2021 strategic plan for Agriculture and Food Authority (AFA) aims to increase local consumption of coffee by at least 5% and also promote production of clean coffee by at least 50% by the year 2020 (AFA, 2016). Due to the industry's effective forward and backward linkages, coffee is currently contributing 8% of the agricultural output (AFA, 2016). Increase in allocative efficiency will increase profit margins to small scale coffee farmers whose production accounts for 65% of total coffee output (Mati, 2016).

Despite increase in area under coffee from 109,000 ha in 2012/2013 crop year to 115,570 hectares in 2018/2019 crop year, profit margins from coffee have been on decline (ICO, 2019). Export licensing, growing inequality to value addition, minimum volumes for export and quality standards act as entry barriers for small scale coffee farmers to international markets leading to reduced economic incentives and low profit margins (AFA, 2016). Returns from coffee are majorly influenced by international market price and therefore beyond the farmers' control. However, increasing coffee productivity, which is largely within the farmers' control, would therefore mitigate the cost of production and hence improve incomes (AFA, 2016). Despite the decrease in coffee exports, coffee is still a major cash crop in many parts of the central highlands of Kenya and parts of western Kenya. In Embu County, coffee is one of the major industrial and export crops whereby nearly 70% of the crop is grown by smallholder farmers (GoK, 2013a). There is immense need to promote the crop by establishing linkages with government and private research institutions, disseminate market information, conduct farmers training programs, and develop varieties suitable for different agro-ecological zones (GoK, 2013b). These efforts are made to enhance productivity, product quality and competitiveness both in local and global markets. Increase in coffee productivity would reduce poverty, increase household income, stabilize market prices and hence increase household consumption and saving (GoK, 2007). High quality coffee will compete globally, and guarantee high prices and market access to enhance profitability and incomes to rural populations given the available technology among the small scale coffee farmers, hence the need to evaluate profit efficiency for these farms. Provision of adequate economic incentives to farmers could be the missing link between technology development and technology adoption in the coffee sub sector.

Agricultural technology adoption decisions are usually intertwined. Most studies to examine the impacts of agricultural technology have focused on single technology adoption choice and ignored interdependence among technologies (Kassie et al., 2018). Coffee production, both small and large scale farmers behave rationally and will be motivated to produce more in the current period if there was a guarantee of high prices in the previous period (Maitha, 1974). There are other non-price factors such as cost of inputs, labour costs and access to credit that influence production and export supply response of coffee in Kenya (Were et al., 2002). High production and transaction costs accompanied by declining productivity have adversely reduced coffee profitability but with a price incentive to farmers, there will be an increase in coffee returns (Were et al., 2002).

Effective technology development must ultimately increase the farm's profits or decrease its losses (Afolami et al., 2015). Several studies have focused on factors that influence technology adoption (Mignouna et al., 2010; Ak udugu et al., 2012; Musaba and Bwacha, 2014), such as farm size, credit access, expected pay off from technology adoption, extension services and education, but limited consideration on the effects of technology adoption on farm gross returns. Other studies (Chemura et al., 2010; Mohammed et al., 2013; Van der Vossen et al., 2015) were experimental (under controlled conditions) in considering one factor like organic manure or fertilizer at a time without considering possibilities of input substitution during the production process. Over the years, the Kenyan Government through Coffee Research Institute (CRI) has been conducting on-station research on coffee production and management. However, the research institute has been focusing on on-station research with limited on-farm research and technology transfer to assess the impact of research recommendations on gross returns at farm level. Inadequate empirical studies on relative economic efficiency of small scale coffee farmers is proving difficult for policy makers and researchers to reassess the impact of the released technologies at the farm level.

Research on coffee (on station) through Coffee Research Institute has recommended the following: improved crop technologies; disease resistant varieties (Ruiru 11 and Batian), recommended spacing, fertilizer, fungicide, herbicide and pesticide rates and canopy management for increased profitability and reduced cost of production. Disease resistant varieties are meant to reduce cost on agrochemicals for control of coffee berry disease and coffee leaf rust and also improve on the

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marketable value of coffee produced. The objective of this study was therefore to determine the effect of these recommended improved crop technologies on coffee profitability among the smallholder coffee farmers in Embu County, Kenya. The study undertook an in-depth analysis of gross margins and returns per shilling invested in coffee production through optimum input allocation among the smallholder coffee farmers in the county. An issue of great importance to policy makers is the gross margins' responsiveness for coffee given the recommended improved crop technologies, factor demands and prices which interact with other socioeconomic factors at the farm level. Therefore, understanding the reasons for decline in coffee returns and whether it may be reversed remains an important concern in Embu County, Kenya.

MATERIALS AND METHODS

Description of study area

The study covered Manyatta and Runyenjes sub-counties of Embu County which are the main coffee growing zones in the County and are mainly located in Upper Midland (UM) Zone 2-3 Agro-ecological zones (Ndirangu et al., 2017). The rainfall pattern in the study area is bimodal with two distinct rainy seasons. Long rains occur between March and June while the short rains occur between October and December. Rainfall quantity ranges between 1120-1495 mm annually with altitude ranging from 1600 to 1800 m above sea level. Temperatures range from a minimum of 12°C in July to a maximum of 21.6°C in March (GoK, 2013a). Agriculture is the main driver of the economy in the region with over 70% of the farmers being smallholders (MoA, 2011). The main industrial crops in the area are coffee and tea.

Sample size

The sample size for the study was 376 smallholder coffee farmers from the two sub-counties which was obtained from a population of 20,000 registered farmers in the sampled cooperative societies. The following formula was used to determine the sample size as recommended by Cochran (1963) and adopted by Muriithi (2016).

$$n_o = \frac{Z^2 pq}{e^2} \tag{1}$$

Where n_0 = required sample size

Z = t value at 95% confidence level from normal table (1.96)
p = probability that respondent has characteristic being measured
q = (1-p) probability that respondent has no characteristic being measured
e = 5% level of significance (0.05)
Using Equation 1 and assuming 50% probability that the respondent has the characteristic being measured, the sample size was calculated as shown below;

$$n_o = \frac{(1.96)^2 (0.5)(0.5)}{(0.05)^2} = 384 \tag{2}$$

Given that the estimated target population was less than 100,000; then the sample size was adjusted using the following equation for finite population correction (Cochran, 1963).

$$n_o = \frac{n_o}{1 + \frac{(n_o - 1)}{N}} \tag{3}$$

$$n_0 = \frac{384}{1 + \frac{(384-1)}{20,000}} = 376 \text{ farmers} \tag{4}$$

Where n_0 = required sample size, N = total population (registered members)

Sampling procedure

Coffee cooperatives play a crucial role in provision of key inputs, affordable credit to farmers and also provision of social capital for local expertise and profits. The study applied multistage stratified random sampling to select the farmers to be interviewed. The study selected six cooperative societies; major three from each of the two sub counties. Out of the six cooperative societies selected, probability proportional to size sampling criteria using the random number register was employed to select 376 farmers from among the farmers who deliver coffee to the selected cooperative societies. The number of farmers from each cooperative society was determined using the following formula as applied by Ndirangu et al. (2017);

$$k = \frac{p}{M} * 376 \tag{5}$$

Where, k = number of farmers to be interviewed
p = number of members in a cooperative society
M = total number of smallholder coffee farmers in the selected cooperative societies

Data collection

The study used primary production data from various respondents for one crop season (2017/2018 crop year). The primary data were collected from the respondents using structured questionnaires. The key production variables were improved coffee varieties, spacing (tree population), fertilizer types and rates, fungicide types and rates, pesticide types and rates, adoption of capping and level of capping, as well as herbicide types and rates. The recommended practices as detailed in Coffee Research Institute Technical Circulars No. 804, 203 and 502 for all the above technologies were evaluated against farmers' practice (CRI, 2018). If a farmer was using the recommended rate was considered to have adopted and vice versa compared to the recommended rates. Other variables considered were coffee output, factor prices, variable costs and expenditure on labour and output prices for estimation of gross margins and returns on investment in coffee production. Data were also collected on socioeconomic factors of the respondents such as gender of the household head, education level, farm size, credit access, off-farm income and land ownership (title deed). The data collected were processed in Microsoft Excel sheets and coded before analysis.

Data analysis

Descriptive statistics were used to analyze the demographic characteristics of the farmers hypothesized to influence coffee profitability. To determine the effect of recommended technologies on coffee profitability, profit function model was used to show the relationship between coffee gross returns (profitability) with recommended technologies, factors of production used, factor prices and the farm socio-economic factors. The profit function model was preferred since the function is able to derive indirect estimates that link the coefficients of the profit function with those of the production function since it incorporates the factors of production (Adesina and Djato, 1996). The general stochastic profit model is specified as applied by Adesina and Djato (1996):

$$\ln \pi^* = \ln A + \sum \beta_k D_k + \sum \beta_i \ln W_i + \beta \ln Z_2 + \sum \beta_j \ln Y_j + \sum \beta_n Z_n - \beta_w \frac{w_i x_i}{\pi^*} - \varepsilon \quad (6)$$

Where ln = Natural logarithm, π^* = normalized profit, $\ln A$ = constant or intercept, β = vector parameters to be estimated, D = dummy variables for recommended technologies (1 = adopted, 0 = non adoption), W = factor prices, Z_2 = land size under coffee, Y = cost of variable inputs, Z = socioeconomic factors, w_i = wage rate per man day normalized by price of coffee, x_i = number of man days of labour used in production, k = 1,2,…11, i = 1,2,…6, j = 1,2,…6, n = 1,2,…9, D_1 = variety dummy, D_2 = spacing dummy, D_3 = fertilizer dummy, D_4 = foliar feed dummy, D_5 = manure dummy, D_6 = fungicide dummy, D_7 = herbicide dummy, D_8 = pesticide dummy, D_9 = pruning dummy, D_{10} = capping height dummy, D_{11} = heads per stem dummy, W_1 = normalized fertilizer price per kg, W_2 = normalized foliar price per litre, W_3 = normalized manure price per 15kg bucket, W_4 =normalized fungicide price per kg, W_5 = normalized herbicide price per litre, W_6 = normalized pesticide price per litre, Y_1 = fertilizer cost, Y_2 = foliar cost, Y_3 = manure cost, Y_4 = fungicide cost, Y_5 = herbicide cost, Y_6 = pesticide cost, Z_1 = gender, Z_2 = age, Z_3 = education, Z_4 = experience, Z_5 = household size, Z_6 = off farm income, Z_7 = land ownership, Z_8 = extension, Z_9 = credit access and ε = error term.

RESULTS AND DISCUSSION

Farm and farmers' characteristics of the respondents

Table 1 shows the demographic characteristics of the respondents in the study area hypothesized to influence coffee profitability. The findings indicated that 74.7% of the respondents were males, while 25.3% were females implying that majority of the coffee farms in the study area were managed by males due to intensity of farm operations involved. Men controlled key production resources such as land, capital hence dominated coffee production. Mohammed et al. (2013) and Nguezet et al. (2011) found the impact of gender on household income significantly higher in households headed by male than in those headed by females. Majority (75.8%) of respondents had attained secondary education and above (Table 1), implying diverse knowledge and basic skills which would play a key role in managing risks, taking mitigation strategies and long term production decisions. These findings concur to that by Akudugu et al. (2012) and Mignouna et al. (2010) that formal schooling was key in critical production decisions. Majority of farmers (77.6%) owned one acre of land and below and this was attributed to land fragmentation associated with population growth, leading to small and uneconomical land sizes for crop production (Murimi et al., 2019).

The study further showed that majority of the respondents (70.5%) had access to credit (Table 1), implying that farmers had access to key farm inputs and other efficiency enhancing technologies. The credit also provided a cushion against production risks and random shocks for increased coffee productivity. Credit access was a key facilitating factor of production and technology adoption (Akudugu et al., 2012; Chepng'etich et al., 2015). The family sizes in the study area comprised between 4-6 members (69.7%) per household which was an indication of a source of family labour for various farm operations. Mohammed et al. (2013) and Nguezet et al. (2011) found household size significantly and positively related to household income. In addition, less than half of the respondents (43.4%) had land ownership rights in form of land title deed, implying that majority of the respondents did not have security of land tenure. This was likely to negatively impact on coffee profitability, as farmers could not make long term investments due to uncertainties in the long run.

Estimation of gross returns (margins) from coffee enterprise

The study hypothesized that variations in coffee profitability were due to differences in input use, adoption of recommended technologies with interaction of farm socioeconomic characteristics of the farmers. The study analyzed the gross returns across the farms in the sample and descriptive statistics results are given in Table 2.

The results showed that coffee production was profitable despite some farmers making losses due to high cost of production. Although some farmers incurred losses, the gross margin averaged Kshs 37,400 ($ 374) per farm. Results of gross margin per tree had a mean of Kshs 249 ($ 2.49) and a standard deviation of 296.603. Gross margin per man day was estimated to be Kshs 1,052 ($ 10.52) with a standard deviation of1462.44 due to variations in labour usage. Gross margin per acre averaged Kshs 80,670 ($ 806.70) and a standard deviation of 115835.62. The study analyzed returns per

Table 1. Farm and farmer characteristics of the respondents.

Socioeconomic factors	Frequency	Percentage
Gender of the farmer		
Male	281	74.7
Female	95	25.3
Level of education		
Non formal	12	3.2
Primary	79	21
Secondary	245	65.2
Tertiary	38	10.1
Other	2	0.5
Farm size (acres)		
0 -0.5	111	29.5
0.51- 1.0	181	48.1
1.01- 1.5	39	10.4
> 1.5	45	12
Credit access		
Yes	265	70.5
No	111	29.5
Off-farm income		
Yes	323	85.9
No	53	14.1
Household size		
1 - 3	74	19.7
4 - 6	262	69.7
7 - 9	40	10.6
Land ownership (title deed)		
Yes	163	43.4
No	213	56.6

Table 2. Descriptive statistics on gross Margins (Kshs) from coffee production.

Returns (Kshs)	Min	Max	Mean	Std. Error	Std. deviation
GM	-30,450	552,897.20	37400	3318.95	64356.80
GM / tree	-268	3547	249	15.296	296.603
GM / man day	-1155	8353	1052	75.42	1462.44
GM / acre	-150,224	876755.60	80670	5973.77	115835.62
GM/shs	-0.72	11.37	1.7612	0.09074	1.75942
Returns/ Kshs	0.28	12.37	2.7612	0.09074	1.75942

GM = Gross Margin.

shilling invested in coffee production and found that for each shilling invested it generates Kshs 1.37 giving returns of Kshs 2.37 with a difference of one shilling. This gave an indication of positive returns or earnings for every shilling invested making coffee production a profitable enterprise.

Table 3. Descriptive statistics for variable costs per acre.

Factor	Unit	Price/unit	Av. cost	%TVC	S. E	Std. deviation
Fertilizer	kilogram	55.68	19628.61	19.8	759.89	14734.80
Foliar feed	Litre	956.20	7287.86	7.4	489.77	9497.06
Manure	Bucket (15 kg)	36.78	22427.12	22.7	1237.04	23987.14
Fungicide	kilogram	1057.60	10210.57	10.3	578.72	11221.74
Herbicide	Litre	782.16	3464.23	3.5	321.52	6234.60
Pesticide	Litre	1029.97	4670.30	4.7	281.83	5464.92
Labour	Man-day	307.20	31313.10	31.6	1486.21	28818.62

Estimation of variable costs for coffee production

The costs of major variable inputs used in coffee production are given in Table 3. The results show that the average price of fertilizer per kilogram was Kshs 55.68 ($ 0.55) with average expenditure on fertilizer being Kshs 19,630 ($ 196) per acre. Expenditure on fertilizer constituted 19.8% of total variable cost implying a key factor of production in coffee. Expenditure on foliar feed was 7.4% of total variable cost with an average of Kshs 956 per litre. Organic manure which acted as a substitute for inorganic fertilizer constituted 22.7% of total variable cost and an average expenditure of Kshs 22,400 per acre.

Fungicides which were commonly used for control of coffee berry disease (CBD) and coffee leaf rust (CLR) constituted 10.3% of total variable cost with average cost of Kshs 10,210.57 ($ 102.10) per acre and an average price of Kshs 1,057.60 ($ 10.57) per kilogram. Expenditure on herbicides constituted 3.5% of total variable cost with an average expenditure of Kshs 3,464.23 ($34.64) per acre. Pesticides constituted 4.7% of total variable cost with an average price of Kshs 1,029.97 ($ 10.29) per litre and an average expenditure of Kshs 4,670.30 ($46.70) per acre. Labour cost varied across the farms given the scale of production constituting majorly on total variable cost with 31.6% and average expenditure of Kshs 31,313.10 ($ 313.13) per acre. The average wage rate per man day was Kshs 307.20 ($ 3.07).

Effect of recommended technologies on coffee profitability (gross margin)

A stochastic normalized restricted profit function was used in the study to show the responsiveness of the predictor variables on gross margins per acre across the farms. Multiple correlation coefficient or coefficient of determination (R^2) is the proportion of variance explained by the regression model making it useful as a measure of success of predicting the dependent variable from the explanatory variables (Nagelkerke, 1991; Hanson, 2010). R square (R^2) should lie between 0 and 1 which is invariant to units of measurement and becomes larger as the model fits better (Magee, 1990).

The fitted model gave a coefficient of determination value (R^2) of 0.724, which implies that the predictor variables explained 72.4% of the observed variation in gross margins per acre. Results revealed a standard error of the estimate of 0.69168 which was the difference between actual and the predicted scores in the null hypothesis. The results also revealed an F-value which was significant at 1% level ($p<0.01$), implying that the predictor variables explained highly significant variation in the dependent variable. Variance Inflation Factor (VIF) measures the impact of multicollinearity among predictor variables in a regression (Robinson and Schumacker, 2009). The general rule is that the VIF should not exceed 10 (Belsley and Kuh, 1980). The predictor variables fitted in the model had a VIF value of less than 5 which implied no problem of multicollinearity between the variables.

The results of the multiple regression using the estimated profit function for the amounts of inputs used and their prices, recommended application rates and expenditure are shown in Table 4. The prices of inorganic fertilizer, fungicide, herbicide and pesticide were not significant in explaining profit variations. However, adoption of the recommended coffee varieties, rate of manure application and labour wage rate were found to have significant ($p<0.05$) positive effects on coffee profitability. On the other hand, capping of coffee stems (bearing heads) and the price of manure and foliar fertilizer had negative significant ($p<0.05$) effects on coffee profitability.

The coefficient for the recommended coffee varieties was positive 0.114 and significant at 5 % level ($t = 2.19$, $p < 0.05$), implying that the gross margin for adopters of recommended coffee varieties (Ruiru 11 or Batian) was 11.4% higher than that of non-adopters. The improved varieties (Ruiru 11 and Batian) were resistant to coffee berry disease (CBD) and coffee leaf rust (CLR) hence produced relatively higher yields of high quality and reduced the cost of production. This increased the marketable value of cherry which guaranteed high returns. These findings concur with those reported by other researchers on impact of improved coffee varieties on sustainable coffee production and profitability among

Table 4. Multiple regression results for effect of recommended technologies and socioeconomic factors on coffee profitability.

Dependent Var.(Profit)	Beta	Std. Error	t	Sig.	VIF
(Constant)	2.54	2.594	0.979	0.329	
Coffee varieties	0.114	0.125	2.19	0.030*	1.414
Tree spacing	-0.067	0.117	-1.397	0.165	1.217
Recommended fertilizer rate	0.008	0.116	0.171	0.865	1.262
Recommended foliar feed rate	-0.066	0.148	-1.051	0.295	2.066
Recommended manure rate	0.204	0.227	3.96	0.000***	1.397
Recommended fungicide rate	0.034	0.148	0.574	0.567	1.797
Recommended herbicide rate	-0.094	0.147	-1.547	0.124	1.937
Recommended pesticide rate	-0.075	0.121	-1.572	0.118	1.179
Pruning	-0.017	0.433	-0.372	0.710	1.156
Capping	-0.128	0.177	-2.554	0.012**	1.318
Heads per stem	-0.023	0.117	-0.474	0.636	1.267
Expenditure					
Fertilizer price	0.012	0.143	0.161	0.872	2.800
Fertilizer variable cost	0.118	0.159	1.474	0.143	3.381
Foliar feed price	-0.182	0.15	-2.204	0.029*	3.564
Foliar feed variable cost	-0.259	0.153	-3.291	0.001***	3.239
Manure price	-0.516	0.152	-7.026	0.000***	2.829
Manure variable cost	-0.398	0.145	-5.634	0.000***	2.612
Fungicide price	0.032	0.129	0.565	0.573	1.657
Fungicide variable cost	-0.121	0.138	-1.971	0.051	1.984
Herbicide price	0.061	0.123	0.878	0.381	2.533
Herbicide variable cost	-0.076	0.139	-1.174	0.242	2.212
Pesticide price	-0.038	0.118	-0.592	0.555	2.183
Pesticide variable cost	-0.031	0.117	-0.503	0.616	1.986
Wage rate	0.321	0.018	6.743	0.000***	1.192
Socioeconomic factors					
Land size (acres)	0.081	0.124	1.110	0.269	2.788
Gender (male=1, female=0)	0.058	0.148	1.164	0.246	1.298
Age of the farmer (years)	0.037	0.094	0.672	0.502	1.619
Level of education	0.024	0.102	0.444	0.658	1.540
Experience (years)	-0.021	0.117	-0.381	0.704	1.591
household size (number)	-0.042	0.108	-0.828	0.409	1.368
Off farm income (yes=1, no=0)	0.005	0.178	0.084	0.933	1.518
Land ownership (tenure)	-0.009	0.118	-0.19	0.850	1.305
Extension service (yes=1, no=0)	0.002	0.184	0.041	0.967	1.200
Credit access (yes=1, no=0)	-0.045	0.136	-0.918	0.360	1.245

***significant at 0.1%; **significant at 1%; *significant at 5%.

arable farms (Andrew and Philip, 2014; Van der Vossen et al., 2015; Haggar et al., 2017). However, Musaba and Bwacha (2014) found impact of improved maize seed varieties insignificant in influencing farm returns due to recycling of the planting materials. The coefficient of recommended manure rate per tree was positive 0.204 and significant at 5 % level (t = 3.96, $p < 0.01$). This implied that the gross margin for adopters of recommended manure rate was 20.4% higher than that of non-adopters. Apparently, manure use acted as a substitute for inorganic fertilizers which were relatively expensive. Organic manure has been used as a strategy for climate change and sustainable production with reduced impact on the environment, which would in turn increase environmental-economic benefits and trade-offs for sustainable production and high returns on coffee farms. Similar results were reported by Chemura et al. (2010); Mohammed et al. (2013) and McArthur and McCord (2017). On the contrary, Musaba and Bwacha (2014) found manure use insignificant in explaining variations in returns from maize production due to allocative inefficiencies.

The coefficient of recommended capping was -0.128 and significant at 5% level (t = -2.55, $p < 0.05$), implying that gross margin for adopters was lower than that of non-adopters by 12.8%. These findings concur with Van Asten et al. (2011), Castro et al. (2013) and Perdoná and Soratto (2015) on effect of capping and coffee returns. Capping would lead to dense canopy and shade thus limiting light penetration. Dense canopy would also act as alternate host for pests which would lead to expenditure on agrochemicals, reducing the production potential of coffee trees hence negatively influencing coffee returns (Gordon et al., 2007). Capping would also increase the cost of hired labour due to increased demand for pruning. However, capping is recommended in coffee estates to guide nutrient flow towards fruit bearing branches, enhance farm management and to facilitate coffee harvesting. However, Ghosh and Bera (2014) found capping significant and positively related to profitability of sweet oranges.

The price of foliar feed had a negative coefficient of 0.182 and significant at 5% level (t = -2.204, $p < 0.05$), implying that a 10% increase in unit price of foliar reduced coffee returns by 1.82%. The coefficient for expenditure on foliar feed had a negative coefficient of 0.259 and significant at 1% level (t = -3.29, $p < 0.01$), implying that a 10% increase in expenditure (amount used and the price) on foliar feed decreased coffee returns by 2.59%. The negative effect on gross margin implies that the increased coffee value from foliar fertilizer is lower than the price paid for foliar fertilizer. Foliar fertilizer is meant to correct micronutrient deficiency and since no soil or leaf analysis had been conducted to ascertain the status maybe its application was not important. The expenditure on foliar feed negatively influenced gross returns given the minimal marginal increase in coffee yields. These findings are similar to those reported by Castro-Tanzi et al. (2012), Alexander (2012), Andrew and Philip (2014) and Komarek et al. (2017) who found cost of foliar to be negatively related to coffee returns.

Manure price had a negative coefficient of 0.516 and was significant at 1% level (t = -7.03, $p < 0.01$), implying that a 10% increase in unit price for manure reduced gross margins by 5.16%. Cost of manure (both price and amount used) had a negative coefficient of 0.398 and significant at 1% level (t = -5.63, $p < 0.01$), which showed that a 10% increase in expenditure incurred on manure decreased coffee profit by 3.98%. This showed that the marginal value for coffee from manure was less than the unit price paid for manure. The farmers were using organic manure as an alternative for inorganic fertilizers and therefore higher prices of manure would result in its inadequate application. Other researchers also reported similar findings that cost of manure and agrochemicals negatively affected coffee profitability (Oerke et al., 2012; Bravo-Monroy et al., 2016; Haggar et al., 2017; Komarek et al., 2017).

Wage rate was positively related to gross margin with a coefficient of 0.321 and significant at 1% level (t = 6.743, $p < 0.01$), meaning that contrary to expectation a 10% increase in wage rate increases coffee profit by 3.2%. The plausible explanation is that hired labour would increase efficiency and supervisory roles given that the farmer incurred cost compared to family labour. Increase in wage rate would act as an incentive and motivation for increased labour productivity hence increased coffee net returns. Increase in wage rate implied that the marginal value product for coffee was more than the price of labour per man-day. These findings concur to those reported by Mohammed et al. (2013), Mathenge et al. (2015) and Kassie et al. (2018) that expenditure on labour use increased coffee returns. Fertilizer price was not significant in influencing the coffee returns since majority of the farmers used manure s an alternative to inorganic fertilizers. Komarek et al. (2017) found increase in fertilizer prices led to a decline in maize yield and household income. At higher fertilizer prices, households applied less fertilizer which had a negative effect on total household income. Socioeconomic factors hypothesized to influence coffee profitability were found not significant (Table 4).

Conclusion

Based on the study findings on effect of recommended improved crop technologies on coffee profitability, results revealed that recommended coffee varieties (Ruiru 11 or Batian) and manure rate had positive and significant effect on coffee gross returns. However, capping was found to have significant but negative effects on coffee returns at the farm level. Factor prices for foliar feed and manure and also expenditure on these inputs also had a significant negative effect on coffee gross returns. The study tested the hypothesis that the recommended technologies have no significant effects on coffee profitability. Therefore, the null hypothesis is rejected and the alternative that the recommended technologies have significant effect on coffee profitability is true.

RECOMMENDATIONS

Based on the study findings, there was evidence of variations in coffee gross returns across the farms. Therefore, the study came up with the following recommendations to guide the farmers and the policy makers in the efforts to increase coffee returns at the farm level.

(i) The farmers should adopt the recommended improved coffee varieties which are Ruiru 11 or Batian for they are disease resistant with high yield potential which will ensure a reduction in cost of agrochemicals hence high net returns.

(ii) The farmers should ensure application of organic manure at the recommended rate of one debe per tree per year as it is an organic substitute for inorganic fertilizer that is not only environmental friendly but also with proven agronomic advantages.

(iii) The farmers should maintain 2 -3 bearing heads to remove weak branches which compete with main fruit bearing branches for nutrients and light and also easiness of other management operations.

(iv) The Kenyan government should formulate an economic policy aimed at stabilizing factor prices of key inputs such as foliar feed and manure as expenditure on them significantly influenced coffee returns. This would in turn improve competitiveness of the crop in the international markets and exchange rate volatility in the long run.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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