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Assessment of Production Cost Affecting Optimization of Coffee Yields in Chuka Sub-County, Tharaka Nithi County, Kenya

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Abstract: *Coffee production is a crucial economic world activity due to its contribution to foreign exchange and employment creation. Areas in other parts of the world that produce coffee have been increasing their output, but in Kenya, there has been a decline in production since 1987. Despite the emergence of other profitable enterprises such as dairy farming in some of the coffee-growing zones, some farmers still have a passion for continuing with coffee production. The Kenyan government has undertaken several measures to mitigate the decline of coffee with the aim of optimizing coffee production. However, despite the efforts to maximize coffee farming, production at the farm level remains low, and some farmers are abandoning coffee production. The annual coffee production is estimated to be about 600 kg per hectare, which is far below the potential output of 2300 kg per hectare. This study determined the influence of the adoption of improved coffee cultivars, fertilizer utilization, and the cost of labour in the optimization of coffee production in Chuka Sub-county, Tharaka Nithi County. Simple random sampling was used to select farmers from ten coffee cooperative societies. A sample of 153 farmers was selected from 7,428 small-scale coffee farmers. The study was based on the Agrarian Transformational Theory, and the Logit model was used to establish the relationship between improved cultivars, fertilizer application, and cost of labour and optimal coffee production. The findings indicated that most of the farmers had planted SL24 and SL 48, which represented 50% and 40%, respectively. The research established that the high cost of fertilizer reduces the application of the input as (70%) of the respondents indicated that they used manure, which provided essential nutrients but in limited amounts. It also revealed that the majority of the respondents (63%) use family labour as the source of labour. There is a need for farmers to adopt improved cultivars and properly utilize production inputs to optimize coffee production.*

Keywords: *Small scale farmers, Coffee, Optimization of production, Cultivars, Labour, Fertilizers*

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I. Introduction

Coffee is one of the top agricultural commodities exchanged in farm markets worldwide. It is the second most traded commodity after petroleum and is a vital source of export earnings for many developing countries where it is produced (Naik and Nethrayini, 2018). Coffee is produced in over 70 countries in the world, with Brazil being the largest producer, which produced 2,595,000 metric tons of coffee beans in 2016 (Adugna et al., 2019). Other large producers in the world include Vietnam, Colombia, Indonesia, Ethiopia, Honduras, India, Uganda, Mexico, Guatemala, among others. European Union, followed by the United States and Brazil, dominates the market for coffee with annual consumption of about 44, 25.3, and 20.5 million 60 Kg bags, respectively (ICO, 2016). Ethiopia, Uganda, Kenya, Cote d'Ivoire, Tanzania, Madagascar are Africa's highest coffee producing countries (USDA, 2018). In these countries, ' coffee export is an important contributor to foreign exchange and a significant proportion of government tax revenue and Gross Domestic Product (Olubiyi et al., 2019). The coffee sector, therefore, contributes to foreign exchange earnings, household incomes, employment, and food security. Coffee has an important role in the national economy and poverty problems that occur in rural areas have the opportunity to be overcome through increased production and added value of coffee commodities (Wahyudi et al., 2020).

In the 25 coffee-growing countries in Africa, 53 percent of the rural population grows coffee, and most of them are small-scale farmers (Murindahabi et al., 2019). Coffee growing provides substantial income to smallholders and functions as a trigger for them to transform their livelihood from subsistence-based to market orientation (Nghiem et al., 2020). In Kenya, it is estimated that 170,000 ha of the country's high potential land area is planted with coffee and the produce command high price in the world market (Krishnan, 2017). Kenya mainly produces varieties of Arabica coffee (SL28, SL34, K7, Ruiru 11, and Batian), which are highly valued in markets worldwide. Kenya coffee production is increasingly smallholder dominated as large plantations, especially those neighboring urban centers, have continually given way to housing development. The

smallholders, who are mainly organized in co-operatives, account for 75.5% of the total land under coffee, while 24.5% is under large estate plantations (Getu and Hill, 2018). However, despite this dominance of smallholders in coffee land acreage, they only account for a 48% share of domestic production (SCAA, 2016).

Smallholder coffee production is faced by the problems of declining output, low productivity, and low income for farmers. Lack of high yielding varieties, changes in climatic conditions, poor management practices, low soil fertility and poor pricing are considered as major constraints of coffee production (Tadesse et al., 2020). A growing international human population and rising living standards are increasing the demand for agricultural products (García et al., 2020) among them being coffee. The crop has continued to perform poorly with a resultant rise in poverty in rural areas where coffee is the major crop. Coffee production is one of the significant agricultural economic activities in Chuka Sub-County that play a major role in the livelihoods of small scale farmers. Despite measures taken by the County government to improve coffee production, the acreage under coffee and the general production continue to decline with smallholders abandoning production of the crop to try other enterprises. Although farmers are shifting to other enterprises, coffee remains a major cash crop in Chuka sub-County. Ignoring the coffee sector will have a negative impact on the economy of the Chuka sub-County, fueling poverty among smallholder farmers. Many factors have affected coffee production in Kenya, but limited research has focused on the cost of producing coffee. This study aimed to assess the effect of the adoption of improved coffee cultivars, fertilizer utilization and cost of labour on optimization of coffee yields in Chuka sub-County

II. Methodology

Study site

The study was carried out in Chuka sub- County in Tharaka Nithi County. Chuka has three wards, namely Karingani, Magumoni, and Mugwe, all covering an area of 308 Km^2. Annual mean temperature ranges from 14-30^{0}C with a total annual rainfall of between 1200- 2200 mm, and the soils are deep, well-weathered with moderate to high inherent fertility (TNCG, 2018). The rainfall is bimodal with long rains occurring from March to June and short rains from October to December.

Research Design

This study applied a descriptive survey design (Omair, 2015), which catered for the collection of the quantitative data. The design was deemed appropriate as it was useful in describing the characteristics of a large population. Questionnaires and structured interviews were used in the study to collect quantitative data. The questionnaire was administered to the coffee farmers in each ward, and interviews were used to provide in-depth knowledge adoption of improved cultivars (Batian, Ruiru 11, and SL 28). The influence of fertilizer cost was determined by factors such as the cost of purchasing and transporting the fertilizer. The reliability of the research instrument was tested using test-retest techniques. The questionnaire was administered twice to respondents comprising of five managers and five treasurers from Manyatta sub-County, in neighboring Embu County. The validity of the instruments was done by consulting small-scale coffee farmers and staff of coffee cooperative societies and the Sub-county Agricultural Extension Officers in Chuka sub-County before conducting the actual study.

Sample size and sampling

A total of 7,428 small scale farmers grow coffee in Chuka sub-County. Random complete block design sampling procedure was used to select a sample of 153 farmers, where each cooperative society was treated as a block. The study used simple random sampling to select the farmers from each of the ten coffee cooperative societies (Rubate, Gitareni, Kabuboni, Kiangondu, Kirubia, Muiru, Mwangu, Ndagani, Magumoni, and Thuita) in Chuka sub-County since the population was mutually homogeneous. In the coffee farmers' strata, the research used Slovin's formula adopted from Cochran (1963) in order to determine the sample size.

$n= N \div [1+N(e)^2]$

Where; n= sample size N= Population size, e= level of significance

$n= 7{,}428 \div [1+ 7{,}428(0.08)^2] = 153$

The sample of 153 was allocated proportionately to each cooperative society according to the proportionate number of growers, as shown in Table 1. The respondents were then selected using a simple random sampling method. During the study, a total of 148 questionnaires were administered and used in data analysis. This was a response rate of 97%.

Data Correction Procedure

Both primary and secondary data were utilized in the study. Primary data was collected through a structured questionnaire. The questionnaire captured various variables affecting coffee optimization. Production cost issues affecting optimization of coffee yields were addressed by the questionnaire. Research assistances administered the study tool to the coffee farmers in Chuka sub-county. The questions were divided into three sections A, B, and C. Section A covered questions based on the adoption of improved cultivars. Section B covered questions on the influence of fertilizers while C covered questions on the influence of cost of labour affecting optimization of coffee production.

Table 1: Coffee farmer's representation per Ward in Chuka sub-County

Name of society	No. of factories	No. of farmers	Sample size	% of respondents
Rubate	2	752	15	9.8
Gitareni	2	460	9	5.9
Kabuboni	1	90	2	1.3
Kiangondu	2	88	2	1.3
Kirubia	3	1299	27	17.6
Muiru	2	272	6	3.9
Mwanga	2	1089	22	14.4
Ndagani	3	1208	25	16.3
Magumoni	2	858	18	11.7
Thuita	3	1312	27	17.6
Total	22	7428	153	100

Data Analysis

The data collected wasanalyzed using the Statistical Package for Social Sciences (SPSS) version 23. Descriptive statistics such as percentages, means, standard deviations, and frequencies were used to interpret the analyzed data. A logit model was used to analyze the data.

$$\ln\Omega_{y\leq m}(x) = \tau_m - x\beta$$

where,

$$\Omega_{y\leq m}(x) = \frac{pr[y\leq m|x]}{pr[y>m|x]} \quad \text{..... 3.2}$$

The logit model can take the following form:

$$p(y = 1|x) = p(y = 1|X_1, X_2 \dots \dots X_k) \quad \text{.....3.3}$$

Where x denotes a full set of the explanatory variable

$$y = \begin{cases} 1, & \text{if the coffee production is optimized} \\ 0, & \text{if the coffee production is not optimized} \end{cases}$$

The fitted probabilities can have the disadvantage of producing values that are less than zero or greater than one. Limitation of variables was avoided by the introduction of, a class of binary response models was formed as follows:

$$p(y = 1|x) = G(\beta_0 + \beta_1 x_1 + \cdots \dots .. B_K X_K) = G(\beta_0 + x\beta) \quad \text{...3.4}$$

Where; G is the logistic function taking on values strictly between zero and one: $0 < G(z) < 1$.

$$G(z) = \frac{\exp(z)}{[1+\exp(z)]} = \Lambda(z) \quad \text{.....3.5}$$

$$x\beta = \beta_1 X_1 + \cdots + \beta_k X_k \quad \text{.....3.6}$$

The percent correctly predicted measure of fit was computed to establish the goodness of fit of response. The percent correctly predicted probability was computed as follows: for each i computed, it was estimated that the probability that y_i takes on the value one, $G(\beta_0 + x_i\beta)$. If $G(\beta_0 + x_i\beta)$>0.5 the prediction of $y_i$is unity, and if $G(\beta_0 + x_i\beta) \leq 0.5$$y_i$is predicted to be zero.

$$\hat{y}_1 = \begin{cases} 1 \text{ if } \hat{y}_1 > 0.5 \\ 0 \text{ if } \hat{y}_1 \leq 0.5 \end{cases} \quad \text{.....3.7}$$

III. Results And Discussion

Coffee Production

The respondents were asked to indicate the quantity of coffee they were producing in kilograms for the last two years. The majority of the respondents (45.8%) indicated that they had been producing between 100 Kgs-199.9 Kgs in 2016/2017, and 41.8% produced the same yields in 2017/2018. The findings of the study showed that there was a decline in coffee production in 2017/2018 as compared to 2016/2017 (Table 2). Production of coffee is highly determined by specific rainfall distribution patterns that affect the flowering of the coffee bushes, disease prevalence, and cherry maturation. The lower rainfall experienced in 2017/2018 might have contributed to a reduction in the quantities of coffee. Respondents were asked to indicate the factors that affect coffee production in the sub-County. Sixty seven (67) percent of the respondents agreed that limited access to credit has contributed to the optimization of coffee production in the sub-County as farmers were unable to meet periodic expenses (Table 3).

Table 2: Coffee production per farmer (Kgs)

Yield (Kgs)	2016/2017	Percent response	2017/2018	Percent response
1-99.9	14	9.8	30	19.6
100-199.9	69	45.8	64	41.8
200-299.9	29	19.6	25	16.3
300-399.9	24	16.3	20	13.1
400 and above	12	8.5	14	9.2
Totals	148	100	153	100

The study observed that the high cost of farm inputs had contributed significantly to the decline in coffee production since farmers are unable to purchase the necessary inputs such as fertilizers, which boost production. Sixty two (62) percent of the respondents cited the declining coffee prices as causes for the high rate of farmers abandoning coffee production for other enterprises. Low prices reduced the incentive of farmers' to produce quality coffee. The few farmers who produced coffee still received low prices since coffee from different growers is normally mixed during processing and marketing, making all farmers earn the same. The results are summarized in Table 3.

Table 3: Factors that affect coffee production in the sub-County

Factor considered	Mean agreement on 1-5 point Likert scale	Percentage response
Limited access to credit	2.72	67
High cost of farm inputs	2.52	62
High cost of borrowing	1.99	50
Climatic changes	2.51	63
Low coffee prices	2.52	62
Poor coffee production technology	1.90	49
Average	2.36	58.83

Cost related factors affecting optimization of coffee

Respondents were asked to indicate the cost-related factors that affect the optimization of coffee yield. Sixty six (66) and sixty five (65) percent of the respondents indicated that the high cost of both the credit and inputs has contributed to low coffee production and has lowered the optimization of coffee yields. Poor infrastructure in the area also increased the cost of transporting coffee from farms to factories, which reduced coffee earnings lowering farmers' incentive. Availability and high cost of good quality coffee cultivars limited the adoption of improved coffee varieties that produce high yield (Table 4). Harelimana et al. (2018) reported that high production costs face 65 % of the farmers living in developing countries. The author revealed that high inputs cost, cost of transporting the final produce to market, and cost of adopting new technologies increased production cost. However, it is possible that the increase in the cost of one factor, such as the cost of inputs, directly affect coffee optimization. Getu and Hill (2018) indicated that modern farming calls for increased application of inputs such as new seeds variety and fertilizers. Though the farm inputs increase the production, failure to use them may drastically reduce production. Optimized farm production has been reported in farms farmers utilize the farm produce despite the costs incurred.

Table 4: Cost related factors affecting optimization of coffee

Factor considered	Mean agreement on 1-5 point Likert scale	Percentage response
High cost of credit	2.70	66
High cost of inputs	2.60	65
High transport cost	2.11	53
Cost of improved cultivars	2.69	66
Administrative cost	2.23	54
Average	2.47	60.8

Adoption of improved cultivars

The study sought to establish the level of adoption of improved coffee cultivars in Chuka sub-county, which were resistant to diseases as an indicator of optimization in coffee production. The majority of respondents indicated that they had adopted SL 24 and SL 48, representing 50 percent and 40 percent, respectively (Table 5). It was observed that most of the farmers in the study area had planted SL 24 and SL 48, which are highly affected by diseases such as coffee berry diseases and leaf rust that contributes to low coffee production. The study revealed that the costs of buying the new cultivars were high hence reducing the adoption of the cultivars. Harrison et al. (2019) reported that the cost of uprooting the old coffee bushes was high as one had to hire labour, which is costly. Additionally, the study revealed that if a farmer had to adopt a new cultivar, they had to wait for a period of four to five years. The period of four to five years gives time for the newly planted plant to attain a productive stage.

Table 5: Adoption of improved coffee cultivars

Coffee cultivar grown	Frequency	Percentage response
SL 24	71	48
SL 48	58	39
Ruiru 11	5	4
SL 28	6	5
Batian	4	4
Total	148	100

Cost of labour

The respondents were asked to indicate whether the cost of the labour involved in coffee production was high. Seventy percent of the respondents perceived the cost of labour to be very high, which negatively contributes to farmers' optimization of coffee production (Table 6). Household/family labour and hired labour is used for coffee to assist in land preparation, hole digging, weeding, harvesting coffee beans (Nghiem et al., 2020) spraying chemicals, fertilizer application and pruning. Further, the respondents were asked to indicate the source of labour used in coffee production. The majority of the respondents, at 63%, indicated that they use family labour to manage coffee on the farm (Table 6). The findings of the study are in agreement with those of Lyon et al. (2018) who reported that farmers need to hire skilled labour to ensure they manage modern farming and the hired labour had to have skills of weeding, fertilizer application, and disease control. Further, Temple and Ziegler (2019) revealed that farmer labour in recent years has increased and that the cheap labour that farmers used to have had declined due to migrations from rural areas to urban areas. This makes, the available labour expensive to hire, resulting in the application of family labour. In this study farmers indicated that coffee farming is labour intensive and paying for labour was a challenge which resulted to using family labour.

Table 6: Cost and source of labour

Cost of labour	Frequency	Percentage response
High	104	70
Low	44	30
Total	148	100
Source of labour		
Own self	41	28
Family	95	63
Hired	12	9
Total	148	100
Hired labour availability		
Yes	121	82
No	27	18
Total	148	100

The respondents were also asked to indicate whether they normally find enough labour during peak seasons. The majority of the respondents indicated that labour was generally not enough during the peak seasons. Labour demand gets so intense in the coffee harvesting season that contracts are needed in order to secure labourers, but labour demand drops significantly after the harvest (Nghiem et al., 2020). In this study

eighty-two (82) percent of the respondents indicated accessing hired labour was difficult since farmers would not be able to offer attractive wages (Table 6). Much of the available labour was attracted by other enterprises such as the construction of houses and other infrastructure, which offered better pay. The findings of the study were in agreement with a study conducted by (Harelimana et al., 2018). Harelimana et al. (2018) reported that the farming sector does not attract young people who prefer to work in other sectors. On the contrary, the findings of this study were against a finding of Dean (2016), who indicated that hired labour was readily available. Family labour is not very dependable since children, who are great contributors to it are only available during holidays. The majority of the farmers prioritize other enterprises over coffee and therefore, rarely work in their own coffee farms. It was observed that farmers were discouraged by low coffee earnings and therefore gave more attention to enterprises such as tea and horticulture. The cost associated with hiring labour in coffee farms resulted in increased application of own self labour, which is declining due to the emergence of other profitable enterprises.

Cost and use of fertilizer

The respondents were asked if they were satisfied with the prices of fertilizers in the market. Seventy (70) percent of the respondents indicated that fertilizer prices were too high for many farmers to afford (Table 7). The findings supported studies done by Getu and Hill (2018), Verena et al. (2016), and MacNairn (2018), who indicated that farmers opted for farmyard manure. In this study it observed that farmers who were not able to purchase fertilizers were unable to follow the recommended fertilizer application schedule, which affected the optimization of coffee yields. Therefore most of the farmers could not afford to purchase fertilizer, which led to the application of manure as the alternative.

The study further determined whether the farmers were using the recommended fertilizers for coffee production. The fertilizer requirement of coffee is dependent on soil fertility and the level of production. The commonly used fertilizers were CAN at 20%, different types of NPK at 10%, and most farmers used manure at 70% (Table 7). The use of a proper type of fertilizer ensured nutrients were available for use by the crops. The results agreed with the findings of Harrison et al. (2019), Agesa et al. (2019), and Maundu and Karugu (2018), who reported that the cost of the inputs was high. Agesa et al. (2019) indicated that quantities of agricultural produce are determined by the amount and the quality of fertilizer used. The same report indicated that many farmers reduced the application of fertilizer due to lack of subsidies from the government. Maundu and Karugu (2018) revealed that the purported subsided fertilizers are not available to farmers resulting in the increased cost of production. Due to the high cost of purchased fertilizers, many farmers could not manage to follow the required application guideline. It was observed that most farmers preferred to use manure as an alternative, although the levels of essential nutrients may be in limited amounts.

Table 7: Cost and type of purchased fertilizer

Cost fertilizer	Frequency	Percentage response
High	105	70
Low	43	30
Total	148	100
Type of fertilizer		
CAN	29	20
NPK 22:6:12+TE	8	5
NPK 17:17:17	8	5
Manure	103	70
Total	148	100

Logit Model Results

Table 8: Logit model results

Variables	Coefficient estimates	Standard Error	Z	P>|z|	Estimated coefficient (log odds ratio
Adoption of improved cultivars	1.5193	0.4364	3.49	0.000***	4.5685
Cost of labour	-0.1899	0.3205	-0.59	0.555	1.2088
Cost of fertilizer	-0.7894	0.4365	-1.82	0.070**	0.67

Log likelihood=-99.99; log likelihood $\square^2$ =88.72; Pseudo R^2 =0.3052; ***, ** significant at 1% and 5% respectively.

The logit model was estimated using the maximum likelihood estimation method with significant at 1% and 5%. The log-likelihood for the fitted model was -99.99, and the log-likelihood chi-squared value was 88.72, which indicates that all the parameters are jointly significant at 5%. Pseudo R^2 of 0.3052 was also above the

statistical threshold of 20%, confirming that the optimization of coffee was attributed to the covariates considered in the model. Adoption of improved cultivars positively and significantly contributed to optimum coffee production. The possible explanation for this is that those farmers who have adopted the improved cultivars produce more coffee than the farmers planting traditional coffee. The cost of labour has a negative impact on the optimal production of coffee, as an increase in the cost of labour leads to a reduction in the volume of coffee produced. Moreover, the cost of fertilizer also has a negative impact on the optimization of coffee production as an increase in the cost of the input results in increased cost of coffee production, which results in suboptimal coffee production.

IV. Conclusion

The findings of the study showed that from 2016/2017 to 2017/2018, there had been a decline in coffee production, which resulted from failure to adopt improved cultivars, high costs of labour, and high cost of purchased fertilizers. There is a need to promote the adoption of improved cultivars that are resistant to diseases and which are more productive compared to the traditional varieties. Farmers should also be trained on the proper utilization of inputs such as fertilizers, and coffee cooperatives can start the capacity building of the farmers through programs that ensure good coffee agricultural practices.

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