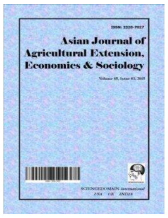

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Evaluation of the Elasticity of Farm Output among Smallholder Farmers in Selected Agro-Ecological Zones of Embu County, Kenya

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Authors' contributions

This work was carried out in collaboration between all authors. Author SNN designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors SGM and OLEM managed the analyses of the study. Author SNN managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aims: Low and declining levels of crop and livestock productivities in the Kenyan agriculture have been attributed to the low application of the key farm inputs. Measures to encourage application of farm inputs with the highest effect on farm output in a given agro-ecological zone (AEZs) have been hampered by lack of adequate and reliable research-based information to guide the choices. The purpose of this study was to evaluate the elasticity of farm output for some selected farm inputs across three different agro-ecological zones (AEZs) in Kenya, using data collected from Embu County in Eastern Kenya as a case study.

Place and Duration of Study: The sample was collected from three agro-ecological zones, namely Sunflower, Coffee and Tea zones, in Embu county, Eastern Kenya between June 2015 and November 2016.

Methodology: The data was collected from a sample comprising 384 farms that were randomly selected using multi-stage stratified sampling employing probability proportionate to size sampling

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procedures. A stochastic log-linearized Cobb-Douglas production function was used to estimate the elasticity of output for the key factors of production.
Results: The elasticity of farm output for labour was found to be significant and positive in the Sunflower (p=.000), Coffee (p=.000) and Tea (p=.000) zones. The elasticity of farm output for fertilizer was significant and positive in the Sunflower (p=.02) and Tea (p=.01) zones. It was only in the Sunflower (p=.01) Zone where the elasticity of farm output for land was found to be significant.
Conclusion: The study recommended that measures be put in place to increase labour usage in the three agro-ecological zones. The study also recommended for increased fertilizer usage in the Sunflower and Tea zones.

Keywords: Agro-ecological zones; output elasticity; land; labour; fertilizer.

1. INTRODUCTION

1.1 Agricultural Policy in Kenya

Vision 2030, the long term development policy blueprint in Kenya, identifies agriculture as being among the key drivers of the 10 percent per annum growth rate envisaged by the Vision [1]. To achieve this goal, the Vision 2030 recognizes the need to transform smallholder agriculture from subsistence to an innovative, commercially oriented and modern agriculture. Smallholder farming dominates agriculture in Kenya and accounts for over 70 percent of total agricultural output. Smallholder farms range from 0.2 to 3 ha in size [2]. Weak farmer institutions result in the poor and inadequate provision of support services to small scale farms [3]. It is the strategy of the Kenyan Government to increase the efficiency of the small scale farmers by strengthening the participation of private sector and farmer organizations in the provision of extension services, affordable credit and farm inputs. In addition, the Government proposes to initiate such programmes as bulk purchasing of the key farm inputs to enhance the capacity of farmer institutions and private sector to provide the inputs efficiently [1,2]. It is also the strategy of the Kenyan Government to provide adequate infrastructure, such as roads, irrigation and marketing facilities, to smallholder farmers.

Low and declining levels of crop and livestock productivities resulting from the low application of the key inputs [2] are cited as being among the main challenges that continue to hamper this transformation. The Agricultural Sector Development Strategy (ASDS), the main agricultural sector policy in Kenya, cites under-exploitation of available arable land for crop production due to lack of coherent policy to guide land use, land administration and delivery systems [2]. In addition, the policy attributes low agricultural productivity to the shortage of labour and increasing dependency on households headed by widows, orphans and elderly people thus leading to households resorting to less labour intensive agricultural activities. The causes of the labour shortage are cited as the disease epidemics and pandemics, such as HIV and AIDS and malaria, and continuous rural to urban migration of youth due to the unattractiveness of agricultural activities.

.Empirical literature reveals a positive elasticity (response) of farm output to the key inputs applied in smallholder farms. A study by [4] found the elasticity of paddy output for fertilizer and labour to be positive but the paddy output elasticity was negative for chemicals. A similar study conducted in by [5] found output elasticity of paddy to be significant and positive for labour, fertilizer and land size. The results from a study conducted by [6] revealed significant and positive output elasticities for fertilizer; labour, and certified seeds for wheat production. A study by [7] compared the maize output elasticity for different farm-sizes. The maize output elasticity for labour and fertilizer was positive in the large, medium and small scale farms, but the output elasticity for certified seeds was only significant and positive in the small scale farms. A similar study on maize conducted by [8] found similar results. The output elasticity of New Rice for Africa (NERICA) was found to be positive for labour, seeds and fertilizer but negative for land [9]. A similar study on Garden Egg (Solanum Spp) found the elasticity of output for land size, labour and fertilizer to be significant and positive [10]. These studies examined the elasticity of output for single enterprises in the farm and are therefore less suitable in informing policy on mixed farming systems commonly found in most countries of Sub-Saharan Africa. The studies also failed to take into account the influence of agro-ecological zones in which the examined enterprises are raised.

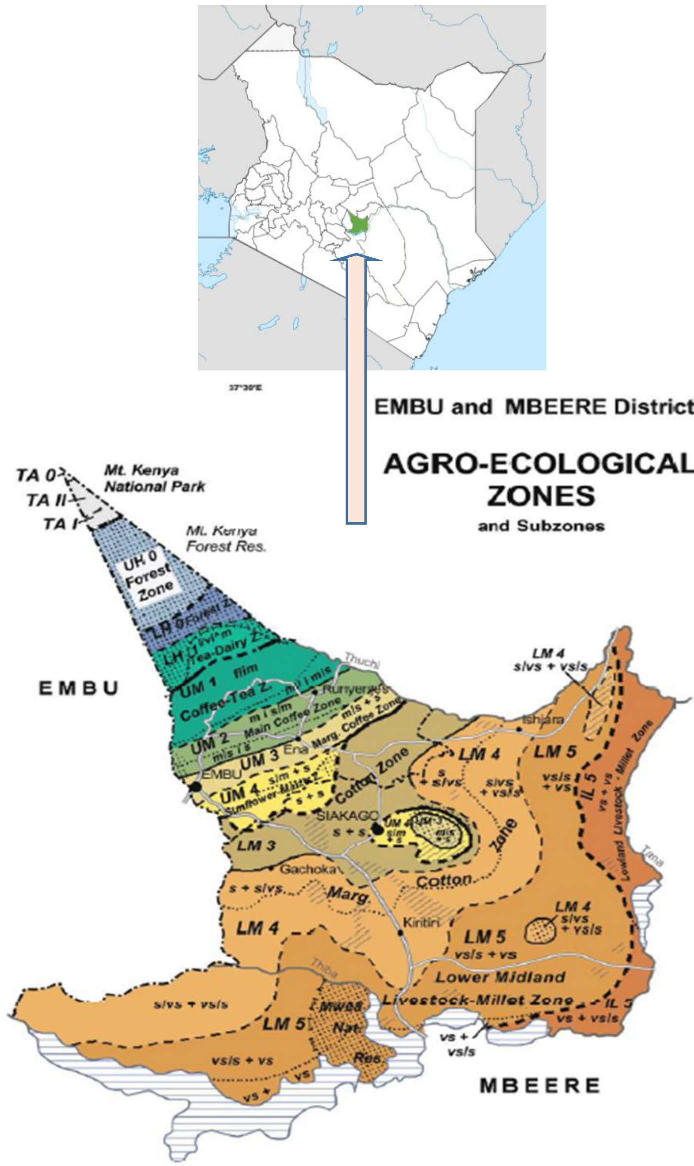

Fig. 1. A Map Agro-ecological Zones of Embu Country in Kenya

The few studies conducted on the output elasticity of the whole farm found it to vary with the regions and enterprises considered. A study conducted by [11] found a significant and positive elasticity of farm output for land size and fertilizer. A study on output elasticity of mixed crop-livestock production system revealed a significant and positive elasticity for land-size and labour [12]. The two studies failed to account for the influence of agro-ecology on the output elasticity. Few studies have examined the influence of agro-ecological factors on elasticity of farm output in a particular region. An earlier study on elasticity of paddy output for selected inputs found that the output elasticity differs significantly across different agro-ecological zones [13]. Agro-Ecological Zoning refers to the division of an area of agricultural land into smaller units, which have similar characteristics that are based on land suitability, potential production and agro-ecological factors. Categorization of agro-ecological zones in Kenya is based on [14].

1.2 Statement of the Problem

The Government's efforts to increase agricultural production through taking measures that increase farm productivity in the heavily fragmented land areas in the country have been hampered by lack of adequate and reliable research-based information to guide the choice of these measures. In the heavily land fragmented areas, one of the ways of increasing farm productivity is to intensify the application of key inputs in agricultural production. There are limited studies done in Kenya to determine farm output elasticity (response) to changes in these inputs. The current study identified two shortcomings in the few studies conducted on farm output elasticity in Kenya. The studies, by failing to take into account the differences in agro-ecological zones, fail to capture the influence of agro-ecology on the elasticity of output with respect to changes in inputs. Again the use of single enterprises to determine farm production reduces the suitability of the studies in informing policies targeted to enhance farm productivity in mixed farming systems commonly found in Kenya.

The purpose of this study was to evaluate the output elasticity of selected farm inputs across three different agro-ecological zones (AEZs) in Kenya, using data collected from Embu County in Eastern Kenya as a case study. The County has relatively small landholdings that are symptomatic of the extent of land fragmentation in the high agricultural potential areas of Kenya. The three agro-ecological zones were the Sunflower-Zone (Upper Midland 4 and Low Midland 3), the Coffee Zone (Upper Midland 1-3) and the Tea Zone (Low Highland 1-2) following the Jaetzold, et al. [14] categorization of the AEZs in Kenya. Fig. 1 gives a map of Embu County showing the various agro-ecological zones and the County's location in Kenya. The study used selected enterprises to determine the total outputs of the farms drawn from the three agro-ecological zones. The selection was based on the proportion of land occupied by the enterprises and their contribution to the total farm production. The specific objective of the study was to evaluate the elasticity of farm output for land, labour, fertilizer and seeds in three agro-ecological zones of Embu County, Eastern Kenya. The study tested the hypothesis that the farm output elasticity for these factors of production are not statistically significant in different agro-ecological zones of Embu County and, by extension, in Kenya.

2. METHODOLOGY

2.1 Sample Size

The elasticity of output for the selected inputs in the study area was measured using a sample comprising 384 farms drawn from the three AEZs. The sample size was determined using the following formula [15]:

$$N = \frac{z^2 pq}{d^2} \quad (1)$$

Where:

N = the desired sample size
Z = the standard normal deviate at the required confidence level
P = the proportion in the target population estimated to have the characteristic being measured
q = 1-p = the proportion of the population without the characteristic being measured
d = the level of statistical significance set

The standard normal deviate was set at 1.96 which corresponds to 95% confidence level. Since there is no available estimate of the target population with the characteristic of interest, 50% was assumed to have that characteristic. The level of statistical significance corresponding to 95% confidence level is 0.05. The sample size was therefore calculated as follows:

$$N = \frac{(1.96)^2 (0.5)(1-0.5)}{(0.05)} = 384 \quad (2)$$

2.2 Sampling Procedure

The study used a combination of a multi-stage stratified sampling and probability proportionate to size sampling procedures. One administrative location was randomly selected from each of the 4 administrative divisions randomly selected from each of the three AEZs making a total of 12 administrative locations selected from the study area. One administrative sub-location was randomly selected from each of the 12 locations, followed by random selection of one administrative village from each sub-location and therefore making a total of 12 villages selected from the study area. The proportion of the village population relative to the total for all the selected villages was used to determine the number of farms to be interviewed in each village. The number of farms to be interviewed in a selected village was determined using the following formula:

$$M = \frac{k}{N} * 384$$

Where:

M = number of farms to be interviewed in a selected village
k = total number of farms in the selected village
N = total number of farms in the 12 villages selected

In total, 134 households were selected for interview in the Sunflower Zone, 133 in the Coffee Zone and 117 in the Tea Zone thus making a total of 384 households.

2.3 Data Collection

The farm production data was collected from the 384 farms using structured questionnaires. The farm production data collected included crop and livestock outputs, inputs used and their respective prices. The study area has two crop growing seasons: the long rain season (March to August) and the short rain season (September to February). To capture the annual farm production data, data were collected during the two crop seasons.

2.4 Empirical Model

A stochastic log-linearized Cobb-Douglas production function was used to estimate the elasticity of output for the key factors of production in different agro-ecological zones. The main advantage of the Cobb-Douglas production function is that it provides parameters that are easy to estimate and interpret [16]. In addition, the use of the function allows the analysis to capture the interaction among the factors of production. The Cobb-Douglas production function used in this study was specified as [13]:

$$LnY = Ln\beta_0 + \beta_1 LnX_1 + \beta_2 LnX_2 + \beta_3 LnX_3 + \varepsilon \quad (3)$$

Where:

Y= Aggregate value of farm output in Ksh.
X_1= land size in ha
X_2= total farm labour in man-days
X_3= quantity of fertilizer applied in Kg.
X_4=quantity of seeds in Kg.
ε= composite error term
β_0, β_1, β_2, β_3 = output elasticity associated with the constant, farm size, labour, fertilizer and seeds
Ln = natural logarithm

The aggregate value farm output was based on three major enterprises which varied with the agro-ecological zones. To enable the study to aggregate different types of outputs, the outputs from the selected enterprises were converted into values using their average farm gate prices. The choice of the enterprises was based on their average contribution to the total farm output in a given agro-ecological zone. In the sunflower zone, maize (44 percent), beans (33 percent) and mangoes (23 percent) were selected for computing aggregate farm outputs. In the coffee zone, maize (28 percent), coffee (29 percent) and bananas (22 percent) were selected. Tea (54 percent), maize (18 percent) and bananas (12 percent) were selected in the tea zone. The selection of the four inputs used in the function was based on their expenditure relative to total production cost.

3. RESULTS AND DISCUSSION

3.1 Descriptive Statistics on farms' Socio-economic Characteristics

Table1 shows the descriptive statistics on characteristics of the smallholder farmers used in the study.

Based on the descriptive statistics given in Table 1, it was found that 50 percent of the smallholder farmers in the sample owned less 0.5 ha of land which indicates a high rate of land fragmentation in the study area. It is also important to note that over 50 percent were over 45 years in age with less than 20 percent of farmers at the youthful stage (less 35 years). This confirms the youth's reluctance to engage in farming as cited in Kenya's agricultural policy [2]. Majority of the farmers (over 50 percent) were also found to engage in other off-farm income generating activities, an indicator of the farms' inability to satisfy the family demand for food and income. However, the farms in the sample were found to have fair access to piped water, electricity and credit at 74, 42 and 56 percent respectively.

Table 1. Descriptive statistics on the socioeconomic characteristics of farmers in the sample

Socio-economic factors	Sample	Sunflower	Coffee	Tea
Farm size (%)				
< 0.50 ha	50	24	66	59
0.50-0.99 ha	23	31	18	22
1.00-1.99 ha	18	28	28	13
>2.00 ha	9	18	4	4
Mean (ha)	0.86	1.3	0.56	0.72
Age (%)				
<35 years	17	13	19	20
35-44 years	26	30	24	23
>45 years	57	57	57	57
Educational level (%)				
None	7	7	9	5
Primary	54	60	48	55
Secondary	30	29	31	31
College & university	9	4	12	10
Off-farm occupation (%)				
None	52	55	49	52
Engaged	48	45	52	48
Household size (%)				
1-3 persons	16	13	19	16
4-6 persons	56	32	25	41
> 6 persons	29	32	23	31
Land tenure (%)				
Rented	2	2	3	1
Without own title	32	32	25	41
Own title	66	66	72	58
Access to piped water (%)				
Access	74	43	89	76
No access	26	57	11	24
Access to electricity (%)				
Access	42	23	51	45
No access	48	77	49	55
Access to credit (%)				
Access	56	37	59	75
No access	44	63	41	25

Source: Field Survey Data, 2016

3.2 Elasticity of Farm Output in Selected Agro-ecological Zones

The parameters of log-linearized Cobb-Douglas model were estimated using the multiple linear regression in computer software SPSS. The β-coefficient associated with a particular input indicates the output elasticity for that input or the response of farm output to 1 percent change in the quantity of the input. The output elasticity for the selected inputs was determined in three different agro-ecological zones.

3.2.1 Elasticity of farm output in the sunflower zone

Table 2 gives the linear regression analysis results showing output elasticity for land-size, labor and fertilizer for the data drawn from the Sunflower Zone. The cost of seeds was found to have a Variance Inflation Factor (VIF) of more than 10, indicating the existence of a serious multicollinearity and was therefore removed from the analysis. The discussions for the empirical results are given thereafter.

Based on the results of linear regression analysis given in Table 2, the farm inputs that were found to have the significant elasticity of production in the Sunflower Zone at levels of 5% level and below are land-size (p=.01), labour (p=.000) and fertilizer (p=.02). The R-square was found to be 0.82, implying that the three factors explain about 82 percent of the total variation in farm output in the Sunflower Zone. The independent variables are discussed separately below:

Table 2.The results of linear regression analysis for the sunflower zone

Variables	β	SE	Sig.	VIF
Constant	1.491	0.352	0.000	
Ln land-size (X_1)	0.101	0.139	0.008	1.018
Ln labor (X_2)	0.765	0.172	0.000	2.962
Ln fertilizer (X_3)	0.156	0.067	0.015	2.959
R-Square	0.819			

Source: Field Survey Data, 2016

Land-size: The land elasticity of production was found to be significant at 1 percent level in the Sunflower Zone (Table 1). The β-coefficient was 0.10, implying that 10 percent increase in farm-size increases the farm output by about 1 percent. Similar findings were found by other studies done in other countries [8,11,17].

Labour: The labour elasticity of production was found to be significant at 1 percent level in the Sunflower Zone (Table 1). The β-coefficient was 0.77, implying that 10 percent increase in farm labour increases the farm output by about 7.7 percent. The results confirm those found by other studies [4,5,12,18,19]. The possible explanation is that an increased labour use in the Sunflower Zone would enable the farmer to expand the land area under crop production and also improve the timeliness of carrying out such farm operations as land preparation, planting weeding and harvesting.

Fertilizer: Fertilizer elasticity of production was found to be significant at 5 percent level in the Sunflower Zone (Table 1). The β-coefficient for fertilizer was 0.16, implying that output would increase by about 1.6 percent per 10 percent increase in quantity of fertilizer used. The possible explanation is that increased fertilizer application in food crop production increases crop productivity thus increasing the farm output. Similar results were obtained by other studies [20,21,22].

Based on the linear regression analysis results, this study specifies the underlying Cobb-Douglas production function in the Sunflower Zone as:

$$LnY = 1.491 + 0.01LnX_1 + Ln0.765X_2 + Ln0.156X_3 \quad (4)$$

Where Y, X_1, X_2 and X_3 are as defined under equation 3

The sum of the computed β-coefficients $(\sum_{i=1}^{3}\beta_i)$ of the function indicates the returns to scale of a given production process [23]. A sum of output elasticity of the inputs less than one ($\sum_{i=1}^{3}\beta_i < 1$) indicates decreasing returns to scale (DRS). A sum equal to one ($\sum_{i=1}^{3}\beta_i = 1$) indicates constant returns to scale (CRS) and a sum greater than one ($\sum_{i=1}^{3}\beta_i > 1$) indicates increasing returns to scale (IRS). The sum of the estimated parameters in the Sunflower Zone was found to be equal to one, implying that a proportionate change in the scale of farm production would change farm output by the same proportion or constant returns to scale.

3.2.2 Elasticity of farm output in the coffee zone

Table 3 gives the linear regression analysis results showing output elasticity for land-size, labor and fertilizer for the data drawn from the Coffee Zone.

Table 3. The results of linear regression analysis for the coffee zone

Variables	B	SE	t	Sig.	VIF
Constant	4.089	0.547	7.473	0.000	
Ln land-size (X_1)	-0.034	0.179	-0.56	0.576	1.298
Ln labor (X_2)	0.855	0.179	11.088	0.000	2.114
Ln fertilizer (X_3)	-0.032	0.058	-0.427	0.670	1.988
Ln seeds (X_4)	-0.066	0.047	-1.106	0.271	1.275
R-Square	0.637				

Source: Field Survey Data, 2016

Based on the results of linear regression analysis given in Table 3, the elasticity of output for labour was the only one that was found to be significant (p=.000) in the Coffee Zone. This confirms the results of other studies conducted by [4,5,6,9,10]. The β-coefficient for labour was 0.86, implying that a 10 percent increase in farm labour in the Coffee Zone increases the farm output by about 8.6 percent. The R-square was found to be 0.637, implying that the inputs considered explain about 64 percent of the variations in farm output in the Coffee Zone. The input elasticity of output for land, fertilizer and seeds were not found to be significant at 5 percent level in the Coffee Zone.

Based on the linear regression analysis results, this study specifies the underlying Cobb-Douglas production function in the Coffee Zone as:

$$LnY = 4.089 - 0.034X_1 + 0.855X_2 \\ -0.032LnX_3 - Ln0.066X_4 \quad (5)$$

Where Y, X_1, X_2 and X_3 are as defined under equation 3

The sum of the computed β-coefficients was 0.72, implying decreasing returns to scale in the Coffee Zone. Therefore, a 1 percent change in the scale of farm production would change farm output by about 0.72 percent, implying decreasing returns to scale.

3.2.3 Elasticity of farm output in the tea zone

Table 4 gives the linear regression analysis results for data drawn from the Tea Zone and the results discussed after that.

Based on the results of linear regression analysis given in Table 4, the output elasticity for labour (p=.000) and fertilizer (p=.01) were found to be significant at 1 percent level. The R-square was found to be 0.860, implying that variations in labour and fertilizer usage explain about 86 percent of the variations in farm output in the Tea Zone. The output elasticity for land was not found to be significant at 5 percent level in the Tea Zone. The farm inputs that were found to have significant output elasticity are discussed separately below:

Labour: The labour elasticity of output was found to be significant at 1 percent level in the Tea Zone (Table 3). The results confirm those found by other studies conducted by [8,10,12]. The β-coefficient was 0.81, implying that 10 percent increase in farm labour increases the farm output by about 8.1 percent. The possible explanation is that an increase in labour use in the Tea Zone would increase the amount of tea picked. The current study found that on average tea contributes about 60 percent of the total farm output in the Tea Zone. In addition, expenditure on labour forms about 75 percent of the farm costs in the Tea Zone.

Fertilizer: The fertilizer elasticity of output was found to be significant at 1 percent level in the Tea Zone (Table 3). Similar results were found by [4,5,7,11,13]. The β-coefficient was 0.14, implying that in the Tea Zone, farm output increases by 1.4 percent per 10 percent increase in fertilizer use. The possible explanation is that increased fertilizer application in tea production would increase its productivity thus increasing the farm output. This study found fertilizer to be a major farm input in the Tea Zone, accounting for about 24 percent of the total farm cost.

Based on the linear regression analysis results, this study specifies the underlying Cobb-Douglas production function in the Tea Zone as:

$$LnY = 2.396 + 0.037LnX_1 + 0.812X_2 \\ +0.0141X_3 - 0.038LnX_4 \quad (6)$$

Where Y, X_1, X_2, X_3 and X_4 are as defined under equation 3

Table 4. The results of linear regression analysis for the tea zone

Variable	B	SE	t	Sig.	VIF
Constant	2.936	0.443	6.628	0.000	
Ln land (X_1)	0.037	0.128	0.821	0.414	1.687
Ln labor (X_2)	0.812	0.114	14.509	0.000	2.555
Ln fert (X_3)	0.141	0.048	2.755	0.007	2.142
Ln seeds (X_4)	-0.038	0.031	-1.247	0.215	1.246
R-Square	0.860				

Source: Field Survey Data, 2016

4. CONCLUSION

The findings of the current study reveal that the elasticity of farm output for labour was significant and positive in all the three agro-ecological zones, implying that increased labour usage in the small scale farms would increase farm output in the three agro-ecological zone. The findings are contrary to earlier studies that found negative marginal productivity of labour in small scale farms (16). However, the study is consistent with the more recent studies that have found positive marginal labour productivity in small scale farms [4,5,12,18,19]. These findings reveal that labour is becoming a more limiting factor in small scale farm production, even in the heavily land fragmented areas.

The output elasticities for land, fertilizer and seeds were, however, found to vary with the type of agro-ecological zones. The output elasticity of land was significant and positive in the Sunflower Zone but was not significant in the Coffee and Tea zones. The possible explanation is that there were significant variations in land size in the Sunflower Zones where more land is still available for agricultural expansion. Sunflower Zone is the aridest among the three agro-ecological zones and hence is the least inhabited and thus has less intensive land fragmentation. The high intensity of land fragmentation in the Coffee and the Tea zones has resulted in small farms with hardly any land available for agricultural expansion.

The output elasticity of fertilizer was significant and positive in the Sunflower and Tea zones where the fertilizer is heavily used in maize and tea production respectively. Contrary to expectations, output elasticity for fertilizer was not significant in the Coffee Zone. A possible explanation could be that the Coffee Zone is dominated by banana and coffee production in which the common practice is to use more manure than manufactured fertilizer.

5. RECOMMENDATIONS

Based on the study findings, agro-ecological zone-specific recommendations were made. These recommendations include instituting measures to attract more labour, particularly the youth, in all the agro-ecological zones. Such measures should include youth education to change their attitude towards farming, enhanced farm level value addition and the introduction of high value crops to boost agricultural productivity. In the Sunflower and Tea zones, measures to increase fertilizer usage are recommended at both the farm and policy level. Other recommendations are to take measures to expand land under crop production in the Sunflower Zone, and such measures include increased access to water for irrigation and introduction of drought tolerant crops.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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