

## Original Research Article

### EVALUATION OF THE ELASTICITY OF FARM OUTPUT FOR SOME SELECTED INPUTS AMONG SMALLHOLDER FARMERS IN THREE AGRO- ECOLOGICAL ZONES OF EMBU COUNTY IN KENYA

#### ABSTRACT

**Aims:** Low and declining levels of crop and livestock productivities in the Kenyan agriculture have been attributed to 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 procedures. A stochastic log-linearized Cobb-Douglas production function was used to estimate 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, which contributes over 70 percent of total agricultural production, from subsistence to an innovative, commercially oriented and modern agriculture. Low and declining levels of crop and livestock productivities resulting from 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 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 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 unattractiveness of agricultural activities.

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 [1]. Weak farmer institutions

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result in 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 Kenyan Government to provide adequate infrastructure, such as roads, irrigation and marketing facilities, to smallholder farmers.

## 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. [4] categorization of the AEZs 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.

## 1.3 Objectives of the study

The specific objective of the study was to evaluate the output elasticity of land, labour, fertilizer and seeds in three agro-ecological zones in Embu County, Eastern Kenya. The study tested the hypothesis that the output elasticity of these factors of production are not statistically significant in different agro-ecological zones in 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 [5]:

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

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:

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

## 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 was collected during the two crop seasons.

## 2.4 Empirical Model

A stochastic log-linearized Cobb-Douglas production function was used to estimate elasticity of output for the key factors of production in different agro-ecological zones. The main advantage of Cobb-Douglas production function is that it provides parameters that are easy to estimate and interpret [6]. 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 [7]:

$$\ln Y = \ln \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \varepsilon \quad (3)$$

Where:

Y= Aggregate value of farm output in Ksh.

X<sub>1</sub>= land size in ha

X<sub>2</sub>= total farm labour in man-days

X<sub>3</sub>= quantity of fertilizer applied in Kg.

X<sub>4</sub>=quantity of seeds in Kg.

ε= composite error term

β<sub>0</sub>, β<sub>1</sub>, β<sub>2</sub>, β<sub>3</sub> = 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

The parameters of log-linearized Cobb-Douglas model were estimated using the multiple linear regression in computer software SPSS. The  $\beta$ -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 were determined in three different agro-ecological zones.

#### 3.1 Elasticity of output for selected inputs in the Sunflower Zone

Table 1 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.

**Table 1: The results of linear regression analysis for the Sunflower Zone**

| Variables               | $\beta$ | 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

Based on the results of linear regression analysis given in Table 1, the farm inputs that were found to have 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:

**Land-size:** The land elasticity of production was found to be significant at 1 percent level in the Sunflower Zone (Table 1). The  $\beta$ -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 [8,9,10].

**Labour:** The labour elasticity of production was found to be significant at 1 percent level in the Sunflower Zone (Table 1). The  $\beta$ -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 [11,12,13,14,15]. 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  $\beta$ -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 [16,17,18]. Based on the linear regression analysis results, this study specifies the underlying Cobb-Douglas production function in the Sunflower Zone as:

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

168 Where Y, X<sub>1</sub>, X<sub>2</sub> and X<sub>3</sub> are as defined under equation 3

169 The sum of the computed  $\beta$ -coefficients ( $\sum_{i=1}^3 \beta_i$ ) of the function indicates the returns to scale of a  
 170 given production process [19]. A sum of output elasticity of the inputs less than one ( $\sum_{i=1}^3 \beta_i < 1$ )  
 171 indicates decreasing returns to scale (DRS). A sum equal to one ( $\sum_{i=1}^3 \beta_i = 1$ ) indicates constant  
 172 returns to scale (CRS) and a sum greater than one ( $\sum_{i=1}^3 \beta_i > 1$ ) indicates increasing returns to scale  
 173 (IRS). The sum of the estimated parameters in the Sunflower Zone was found to be equal to one,  
 174 implying that a proportionate change in the scale of farm production would change farm output by the  
 175 same proportion or constant returns to scale.

### 176 3.2 Elasticity of output for selected inputs in the Coffee Zone

177 Table 2 gives the linear regression analysis results showing output elasticity for land-size, labor and  
 178 fertilizer for the data drawn from the Coffee Zone.

179 **Table 2: 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 <sub>1</sub> )  | -0.034 | 0.179 | -0.56  | 0.576 | 1.298 |
| Ln labor (X <sub>2</sub> )      | 0.855  | 0.179 | 11.088 | 0.000 | 2.114 |
| Ln fertilizer (X <sub>3</sub> ) | -0.032 | 0.058 | -0.427 | 0.670 | 1.988 |
| Ln seeds (X <sub>4</sub> )      | -0.066 | 0.047 | -1.106 | 0.271 | 1.275 |
| R-Square                        | 0.637  |       |        |       |       |

Source: Field Survey Data, 2016

180 Based on the results of linear regression analysis given in Table 2, the elasticity of output for labour  
 181 was the only one that was found to be significant (p=.000) in the Coffee Zone. The  $\beta$ -coefficient for  
 182 labour was 0.86, implying that 10 percent increase in farm labour in the Coffee Zone increases the  
 183 farm output by about 8.6 percent. The R-square was found to be 0.637, implying that the inputs  
 184 considered explain about 64 percent of the variations in farm output in the Coffee Zone. The input  
 185 elasticity of output for land, fertilizer and seeds were not found to be significant at 5 percent level in  
 186 the Coffee Zone.

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

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

190 Where Y, X<sub>1</sub>, X<sub>2</sub> and X<sub>3</sub> are as defined under equation 3

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The sum of the computed  $\beta$ -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.

### 3.3 Elasticity of output for selected inputs in the Tea Zone

Table 3 gives the linear regression analysis results for data drawn from the Tea Zone and the results discussed thereafter.

**Table 3: 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

Based on the results of linear regression analysis given in Table 3, the output elasticity for labour ( $p=0.000$ ) and fertilizer ( $p=0.01$ ) 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  $\beta$ -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). The  $\beta$ -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:

$$\ln Y = 2.396 + 0.037 \ln X_1 + 0.812 X_2 + 0.0141 X_3 - 0.038 \ln X_4 \quad (6)$$

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

## 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

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earlier studies that found negative marginal productivity of labour in small scale farms (6). However, the study is consistent with the more recent studies that have found positive marginal labour productivity in small scale farms [11,12,13,14,15]. 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 for 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 most arid 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.

## 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 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.

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