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The cowpea production function in Uganda: A Cobb-Douglas approach

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Abstract

Cowpea (*Vigna unguiculata*)is one of the important legume crops grown in Uganda, especially in the northern and eastern parts of the country. Using farm data collected through a detailed diagnostic survey in four major cowpea producing districts of Uganda, a Cobb-Douglas model was used to estimate the cowpea production function, using ordinary least squares regression techniques. The returns to scale of cowpea production, marginal productivities and elasticities of the inputs used in cowpea production were estimated from the production function. From the estimated cowpea production function, land, labour and pesticides were the most significant production inputs in that order. The returns to scale of cowpea production were 1.6, 1.7, 2.2 and 1.5 for Arua, Lira, Soroti and Pallisa districts respectively and were significantly different ($P = 0.01$). The returns to scale showed increasing returns in all cases, significant at 1% probability level of significance. The value marginal produtivities of land and capital were greater than the unit costs of these inputs. The value marginal productivities of inputs used for pest control and labour were, however, lower than the unit costs of these inputs. The findings of this study therefore indicate that, increase in cowpea production, in the short run, will generally be achieved by bringing more land under cowpea production, and in the long run, by the use of labour saving technologies such as ox-cultivation and by improving productivity, through better agronomic practices, and better technologies of pest control. Estimation of the cowpea production function at the farm level gave an insight of the most critical factors to consider in increasing cowpea production. The estimation of the returns to scale enables the analysis of the relationship between the size of the cowpea enterprise and profitability, given the available farming technology. The policy recommendations on the improvement of cowpea production given in this paper are based on the above two concepts.

Key Words: Input elasticities, marginal productivity, production function, returns to scale

Introduction

For economic, social and technological reasons, the diet of a large section of the world's population especially in protein content is considered poor (FAO, 1992). Yet proteins of plant origin are relatively cheaper than animal originated proteins. Therefore, increasing supplies of grain legumes (the chief source of plant proteins) offers a potential solution to minimising protein deficiencies in low resource subsistence households. Cowpea (*Vigna unguiculata* (L.) Walp) has been proposed as one of the grain legumes whose inclusion in African cropping systems could substantially improve the nutritional levels of both human and livestock populations, as well as soil fertility (Mehta, 1971). The cowpea is the second most important pulse crop in tropical Africa, with common beans (*Phaseolus vulgaris)* being most important. But the latter is less tolerant to adverse conditions (Purseglove, 1988). In Uganda, cowpea is ranked as the most important legume crop in the northern and eastern regions of the country where beans are grown on a relatively lower scale compared to other regions of the country (Anonymous, 1993). Peak production in Uganda was realised in 1974 when 64,000 metric tonnes of cowpea were produced. After 1974 there was a general decline in production to as low as 20,000 metric tonnes, produced in 1982. The production of cowpeas in Uganda in 1992 was about 40,000 metric tonnes (Anonymous, 1993). This level of production is still very low considering the fact that the Ugandan population is increasing at an average annual rate of 2.5% (World Bank, 1993) and there has been decline in the production of other legume crops such as beans, groundnuts, soybeans, pigeon peas and field peas.

Following the Uganda Government's liberalisation policies in 1990's. there has been a steady increase in domestic demand of the major food crops. There has also been an increasing external demand for a number of food crops due to droughts in neighbouring countries. For instance, in 1994 food crop exports contributed about 40 percent of the total non-traditional exports earnings (BOU, 1994).

The need for strategic planning to take advantage of the regional markets while at the same time ensuring food security at both the farm and national level is critical. Therefore, the principal purpose of this study was to estimate a cowpea production function and measure the responsiveness of cowpea to changes in the quantities of inputs necessary to produce it in Uganda. The specific objectives were: (a) to estimate the input elasticities in cowpea production for selected districts in Uganda, (b) to determine the returns to scale and marginal productivities of the various inputs used in the production of cowpea with the current technology of production, for selected districts in Uganda; and (c) to make policy recommendations, based on the findings of (a) and (b) for the improvement of cowpea production in Uganda.

Methodology

The sample frame comprised of four districts of Uganda namely, Arua, Lira, Soroti and Pallisa that were purposively selected to represent a cross-section of the region where cowpea production is intense using the multiple stage sampling procedure (Poate and Daplyn, 1993). Thirty five households (farms) within the four districts were selected to participate in the diagnostic survey. Data obtained were used to estimate the cowpea production function and returns to scale for cowpea production.

Production Function

The Cobb-Douglas approach was used to estimate the cowpea production function. Agricultural production can be considered as a function of certain input factors such as land, labour and capital. The variation in the levels of these inputs directly affects the gross agricultural production and the cost of production (Halter *et al.*, 1959; Naik, 1965; Boris *et al.*, 1991). A production function can be expressed simply as follows:

$$Y = f(X_1, X_2, \ldots, X_n) \qquad (1)$$

Where Y is the quantity of agricultural output and X_i (i = 1, 2, ..., n) are the various inputs used in production.

According to Naik (1965), the productivity of various input factors is established using the concepts of elasticity of production and marginal productivity. This can be done by fitting a production function to a sample of farms. The Cobb-Douglas type of production function was used because of the advantages of being linear in logarithms and thus empirically simple. It also generates elasticities, permits the calculation of returns to scale and gave the best fit for the empirical data used in this study. It is based on the production function first proposed by Charles W. Cobb and Paul H. Douglas in an empirical study dealing with the productivity of labour and capital in the United States (Cobb and Douglas, 1928). The Cobb-Douglas production function may take the general form of:

$$Y = A X_1^{a1} X_2^{a2} \ldots X_n^{an} \qquad (2)$$

Where Y is the quantity of agricultural output and X_i (i = 1, 2, ..., n) are the various inputs used in production. A and a_i (i = 1, 2,...,n) are constants, a_i is the elasticity of production of factor X_i and $a_i Y/X_i$ is the marginal productivity of X_i.[1] A logarithm transformation of equation (2) gives a linear function

$$\text{Ln } Y = \text{Ln } A + a_1 \text{Ln } X_1 + a_2 \text{Ln } X_2 \ldots + a_n \text{Ln } X_n + e \qquad (3)$$

A and a_i can be estimated from equation (3) using ordinary least squares regression analysis. The statistical significance of these parameters can therefore be established using the t-test, assuming normality of the residuals (Steel *et al.*, 1997). As already indicated in equation (2), the regression coefficients in equation (3), a_i (i = 1, 2, ..., n) are the elasticities for the individual factors of production X_i (i = 1,2, ...,n), respectively. They show approximately the average percentage change in total product which might be forthcoming if the input of any resource, X_i, is increased by one per cent (Heady, 1946). If the elasticity obtained for a particular production factor is more than one, it implies that there are increasing marginal returns for that individual production factor. If, on the other hand, the elasticity obtained for a particular production factor is less than one, it implies that there are diminishing marginal returns of the individual production factor. When negative elasticities are obtained from empirical data applied to equation (3), they are meaningless (Tintner, 1944). This is because it would imply that production would decrease when certain factors of production are increased. However, Alcantara and Prato (1973) suggest that in economic terms, a negative input elasticity implies that the input is being employed beyond the optimal level. In most studies when negative elasticities are obtained, they are usually not statistically significant. From the results of the diagnostic survey it was established that land, labour and pesticides were the most important factors used by farmers in the production of cowpeas (Sabiti *et al.*, 1994). Therefore, the cowpea production function was estimated by incorporating these factors in the following equation:

$$Y_j = A\, LAN^{a1}_j \,.\, LAB^{a2}_j \,.\, PEST^{a3}_j \,.\, CAP^{a4}_j \qquad (4)$$

where
- Y_j = quantity of cowpea produced in district j in kg
- LAN_j = land area devoted to cowpea production in hectares
- LAB_j = mandays of labour devoted to cowpea production
- $PEST_j$ = amount of money used for pest control in USh per hectare per season
- CAP_j = capital invested in cowpea production, measured non-cash cost of depreciation of farm implements used in cowpea production[3]
- j = 1, 2, 3 and 4 for Arua, Lira, Soroti and Pallisa districts, respectively

A, a_1, a_2, a_3, and a_4 are constant parameters which were estimated by taking a logarithm transformation of equation (4) to form a function linear in logarithms similar to equation (3), and then using ordinary least squares regression techniques:

$$\text{Ln } Y_{ij} = \text{Ln } A_j + a_{1j} \text{Ln } LAN_{ij} + a_{2j} \text{Ln } LAB_{ij} + a_{3j} \text{Ln } PEST_{ij} + a_{4j} \text{Ln } CAP_{ij} + e \qquad (5)$$

The subscript i denotes the i th observation in district j, while e is the random error term.

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[1] Cobb, C.W. and Douglas, P.H. (1928). in their article show that a_i equals the elasticity of production x_i.

[1,2] Since there was no standard factor to measure the variability in fertility it is assumed that all the land in a given district is uniformly fertile

[2,3] This is calculated as follows:

$$CAP = \text{Total depreciation} \times \frac{\text{land area of cowpea}}{\text{total crop land}}$$

Characteristics of the estimated production function

(a) Returns to Scale: Returns to scale refers to the behaviour of the change of total returns when all the factors of production are changed simultaneously in the same proportion (Singh and Patel, 1973). It is however not possible for an entrepreneur to have control over all the resources. Therefore in empirical studies only economic returns to scale are generally worked out, including only those factors which are under the control of the entrepreneurs and contribute significantly towards returns. The sum of the regression coefficients (elasticities) of the log-linear Cobb-Douglas production function expressed in equation (3) indicates the returns to scale (Stigler, 1941). If the sum is less than one, it indicates decreasing returns to scale. If the sum is one, it indicates constant returns to scale and if it is greater than one, there are increasing returns to scale. In their study on returns to scale and the productivity of small scale farms in Meerut District in India, Singh and Patel (1973) tested the statistical significance of the returns to scale derived from the elasticities obtained by regression analysis, by an *a priori* assumption of constant returns to scale. They then calculated the t-value of the difference of the returns to scale from unity. The t-value was used to accept or reject the null hypothesis of constant returns to scale. This procedure gives a convenient way of testing the significance of farm data in estimating the returns to scale. In this study, the returns to scale of cowpea production (r_j) under the given technology of production in a given district j were estimated using the equation below and were also subjected to t-tests to establish the significance of the estimated parameters:

$$r_j = a_{1j} + a_{2j} + a_{3j} + a_{4j} \qquad (6)$$

In this way the returns to scale of the production of cowpea was estimated for each specific district.

(b) Marginal Productivity: The marginal productivity indicates approximately the returns which might be expected from the addition of one Uganda shilling (Uganda currency) worth of the various productive inputs. The Marginal productivities of the various input factors were calculated as follows:

$$MP_{LANj} = a_{1j} \,.\, Y/LAN_j \qquad (7)$$
$$MP_{LABj} = a_{2j} \,.\, Y/LAB_j \qquad (8)$$
$$MP_{PESTj} = a_{3j} \,.\, Y/PEST_j \qquad (9)$$
$$MP_{CAPj} = a_{4j} \,.\, Y/CAP_j \qquad (10)$$

where MP_{LANj}, MP_{LABj}, MP_{PESTj} and MP_{CAPj} are the marginal products of land, labour, pesticides and capital, respectively, in the production of cowpea in district j and Y, LAN_j, LAB_j, $PEST_j$ and CAP_j are the geometric means of production, land, labour, pesticides and capital variables in district j, respectively. In calculating the marginal productivity of x_i the geometric means of the sample values of x_i are used (Tintner, 1944; Heady, 1946; Naik, 1965). Data used for national level analysis were obtained from (Anon., 1993)

Results and Discussion

Table 1 shows the coefficients of a_i (i = 1,2,3,4) and constants A_j (j = 1,2,3,4) estimated by applying ordinarily least squares regression techniques applied on equation (5), using the farm data collected from the diagnostic survey. Table 1 also shows the results of the t-tests used to establish the significance of the estimated parameters. At the national level, land (significant at 1% level), labour (significant at 10%) and pest control costs (significant at 10% level) were significant factors in production of cowpea. The estimated elasticities were 1.07, 0.42 and 0.036 for land, labour and pest control costs, respectively. The coefficient of capital (CAP) was negative, contrary to *a priori* expectations and was not significant even at 20% level of significance. The negative coefficient of capital is meaningless since production can not be expected to fall as more capital is invested in production. This strange scenario could perhaps be due to the fact that in most cowpea producing districts, production is at subsistance level and is characterised by use of rudimentary tools such as handhoes with labour saving technologies such as ox-ploughs being limited to only a few areas (Sabiti *et al.*, 1994). Thus extra investiment would not necesarily result into increased productivity because of various production limitation which would require large capital investiments. From these results it is concluded that, in general, land is the most important input in cowpea production (it has the highest elasticity of production and is most significant compared to the other inputs), followed by labour and pest control costs, in that order.

The data from Arua district revealed that land and labour are the only significant (at 10% and 20% level, respectively) inputs in cowpea production. The estimated elasticities for land and labour in Arua

Table 1. Estimated cowpea production function for selected districts of Uganda.

Variable[1]	Unit[2]	Coefficient(a_i) (elasticities) and constants	Standard error of a_i	t-value
National level (pooled data)				
Constant (A)		4.9014***	1.3803	3.5510
Land (LAN)	ha	1.0679***	0.2008	5.3180
Labour (LAB)	MD/ha	0.4182**	0.2006	2.0850
Capital (CAP)	USh	-0.1451	0.1344	-1.0801
Pest control	USh/ha	0.0356**	0.0205	1.7347
Arua District				
Constant (A_1)		6.4891***	0.9757	6.6508
Land (LAN_1)	ha	0.9687**	0.5057	1.9156
Labour (LAB_1)	MD/ha	0.6500*	0.6997	0.9290
Capital (CAP_1)	USh	-0.1303	0.5440	-0.2395
Pest control	USh/ha	-0.0175	0.0748	-0.2341
Lira District				
Constant (A_2)		7.8765***	0.9999	7.8882
Land (LAN_2)	ha	1.0808**	0.6570	1.6451
Labour (LAB_2)	MD/ha	0.6208*	0.6167	1.0065
Capital (CAP_2)	USh	-0.5914	0.3428	-1.7254
Soroti District				
Constant (A_3)		3.3901***	0.9318	3.6382
Land (LAN_3)	ha	1.1102***	0.3215	3.4534
Labour (LAB_3)	MD/ha	0.5047**	0.3481	1.4500
Capital (CAP_3)	USh	0.3991**	0.2585	1.5628
Pest control	USh/ha	0.0606**	0.0460	1.3194
Pallisa District				
Constant (A_4)		2.3313**	1.0470	2.2265
Land (LAN_4)	ha	1.2723**	0.6597	1.9287
Labour (LAB_4)	MD/ha	0.5001*	0.5552	0.9008
Capital (CAP_4)	USh	0.3012*	0.3055	0.8599
Pest control	USh/ha	0.1160**	0.0715	1.6210

*** Significant at 1% level

** Significant at 10% level

* Significant at 20% level

1 see equation (4) for the definition of the variables

2 ha = hactare, MD/ha = Mondays/ hactare, USh.= Uganda shillings, USh/ha = Uganda shillings/hactare.

district were 0.97 and 0.65, respectively. Capital and pest control costs were not significant even at 20% level of significance.

In case of Lira district land and labour were again the only significant inputs (at 10% and 20% level, respectively) in cowpea production. The estimated elasticities were 1.08 and 0.62 for land and labour, respectively. Capital was again not significant even at 20% probability level. Pesticides were not used for cowpea production by the sample of farmers taken from Lira district and therefore pest control costs were not considered in this analysis.

Data from Soroti district revealed that land (significant at 1% level), labour (significant at 10% level), capital (significant at 10% level) and pest control costs (significant at 10% level), are all significant factors in cowpea production. The estimated elasticities were 1.11, 0.50, 0.40 and 0.06 for land, labour, capital and pest control costs, respectively. Basing on the size of the input elasticities, land is the most important input in cowpea production in Soroti district.

Results for Pallisa district were similar to those obtained in Soroti District. Land (significant at 10% level), labour (significant at 20% level), capital (significant at 20% level) and pest control costs (significant at 10%) were all significant in cowpea production in Pallisa. The estimated elasticities were 1.27, 0.50, 0.30 and 0.12 for land, labour, capital and pest control costs, respectively. As in Soroti district, land is the most important input in cowpea production in Pallisa District, basing on the size of the input elasticities, followed by labour, capital and pest control costs in that order.

Comparing the results obtained from the different districts, it is apparent that land is the most important input in cowpea production. In all the four districts land had the highest elasticity of production which in all cases was the most significant, compared to the other inputs. It was also noted that the elasticities of land in Soroti and Pallisa districts, where there is extensive use of oxen for land preparation, were relatively higher than the elasticities of land in Arua and Lira districts, where there is less use of ox-cultivation. The policy implication of these findings about land, is that the most critical issue in increasing cowpea production would be how to bring more land under the crop. Studies in the major cowpea producing areas have shown that cowpea production has high profitability comparable to that of groundnut production, which is the most important competing enterprise (Sabiti, 1995). The net income of groundnut production (293,000 USh per hectare) is higher than that of cowpea (205,800 UShs per hectare), but the returns to labour in cowpea production (2,580 UShs per Man day) is higher than that of groundnut production (1,502 UShs per Man-day). Cotton which is the most important traditional cash crop in the area has a negative net income and returns to labour of only 385 UShs per Man day (Sabiti, 1995). Farmers have not taken advantage of the potential of cowpea as a commercial crop. Labour saving technologies such as ox-cultivation would be appropriate in enabling farmers bring more land under cowpea production.

Labour, like land, was a significant input in cowpea production in all the four districts. However, the elasticities of labour were higher in Arua and Lira districts, where there is less use of ox-cultivation (which is a labour saving technology) compared to Soroti and Pallisa districts where there is more use of ox-cultivation. This indicates that labour input is more critical in Arua and Lira districts and that if Man-days in cowpea production are increased in these districts production is likely to increase by a higher percentage compared to Soroti and Pallisa districts.

Capital is only significant in Soroti and Pallisa districts. This can be explained by the fact that cowpea is largely grown by small scale farmers and apart from ox-ploughs (used mainly in Soroti and Pallisa districts), the hand hoe is the basic implement used in agricultural production. Hence capital is significant only in Soroti and Pallisa districts where there is extensive use of ox-cultivation. Consequently, the level of agricultural production in Pallisa and Soroti districts will depend on whether the farmer possesses ox-ploughs or not. Purchase of ox-ploughs accounted for the largest proportion of capital inputs. The policy implication of this is that since capital, largely accounted for by the cost of the ox-plough, has positive elasticities of production in Soroti and Pallisa districts where ox-cultivation is extensively used, encouraging farmers in Arua and Lira districts to use ox-cultivation, would have a positive impact on cowpea production in these districts when coupled with other technologies. Pest control costs were only significant in Soroti and Pallisa districts where there is relatively more use of pesticides compared to Arua and Lira districts.

In estimating the cowpea production functions (Table 1), the variables which did not turn out to be significant at 20% level of significance were dropped from the equations. Therefore the production fuctions varied depending on districts. The estimated production functions for both national and district level were as follows:

Naional level (Pooled data)

$$Y = 4.9014\ LAN^{1.068^{***}}\ LAB^{0.4182^{**}}\ PEST^{0.0356^{**}} \qquad (11)$$

$R^2 = 0.474 \qquad N = 64$.

Arua District:

$$Y_1 = 6.4891\ LAN_1^{0.9687^{**}}\ LAB_1^{0.6500^{*}} \qquad (12)$$

$R^2 = 0.485 \qquad N = 13$

Lira District

$$Y_2 = 7.8765\ LAN_2^{1.0808^{**}}\ LAB_2^{0.6208^{*}} \qquad (13)$$

$R^2 = 0.678 \qquad N = 10$

Soroti District

$$Y_3 = 3.3901\ LAN_3^{1.1102^{***}}\ LAB_3^{0.5047^{**}}\ CAP_3^{0.3991^{**}}\ PEST_3^{0.0606^{**}} \qquad (14)$$

$R_2 = 0.628 \qquad N = 24$

Pallisa District

$$Y_4 = 2.3313\ LAN_4^{1.2723^{**}}\ LAB_4^{0.5001^{*}}\ CAP_4^{0.3012^{*}}\ PEST_4^{0.1160^{**}} \qquad (15)$$

$R^2 = 0.446 \qquad N = 16$

The returns to scale at national level (r) and in selected districts(r_j) are calculated using the coefficients in equations (11-15) and are given in Table 2. The statistical significance of the calculated returns to scale was tested by making an *a priori* assumption of constant returns to scale (*ie.*, r = 1) and then testing the significance of the difference of the calculated returns to scale from unity, by using the t-test. The results of this analysis are also shown in Table 2. The calculated returns to scale were, 1.62, 1.70, 1.62, and 2.19 for Arua, Lira, Soroti and Pallisa districts, respectively. The combined national data gave 1.52 returns to scale. In all cases the returns to scale were increasing and significant at 1% level of significance. The increasing returns to scale signify that, if all the relevant input factors are increased by a given percentage, then production (Y) will increase by a percentage greater than the percentage increase in the input factors. Therefore, in all the four districts there are advantages of increasing the

Table 2. Estimation of returns to scale of cowpea production in selected districts of Uganda.

Item	Arua (Eq 12)	Lira (Eq 13)	Soroti (Eq 14)	Pallisa) (Eq 15)	National (Eq 11)
Returns to scale (r_j)[a]	1.6187	1.7016	1.6149	2.1896	1.5218
Difference between r & unity	0.6187	0.7016	0.6149	1.1896	0.5218
Degrees of freedom	8	6	19	11	64
Standard error of difference	0.2781	0.1169	0.0324	0.0172	0.0082
t-value	2.2247***	6.0017***	18.9783***	69.1628***	63.6341***
Returns to scale as by t-test	Increasing	Increasing	Increasing	Increasing	Increasing

*** significant at 1% level

[a] Calculated using coefficients in equations (11-15)

relevant input factors, used in the production of cowpeas, assuming that the purely competitive model holds with constant input and output prices. Therefore, farmers should be encouraged to take advantage of higher profits obtained by producing on a larger scale..

Table 3 shows the calculated marginal productivities. The marginal productivities were calculated for only the relevant inputs which turned out to be significant in the estimation of the various production functions. In order to deduce accurately the implications of the calculated marginal productivities, the value marginal productivity (VMP) of each of the relevant inputs in the various districts was calculated. The value marginal productivities were calculated by multiplying the respective marginal productivities with the market price of cowpea. An average rural market price of USh 400 (US$ 0.30) was used for this analysis.

Considering the VMP of land, the results in Table 3 indicate that, an increase of 1 hectare of land in the production of cowpea, increases the farmers returns by USh 219,200, 145,400, 93,560 and 269,440 in Arua, Lira, Soroti and Pallisa districts, respectively. The VMP of labour were USh 272, 564, 272 and 648 for every man day/ha increase in labour for cowpea production in Arua, Lira, Soroti and Pallisa districts, respectively. The VMP of labour for all the districts except Pallisa district was, however, lower than the average rural wage rate (US 600). The VMP of capital was USh 1.6 and 3.6 per USh increase in the money invested in implements used in cowpea production in Soroti and Pallisa

Table 3. Estimation of the marginal productivities of various inputs in cowpea production of selected districts of Uganda.

Variable	Unit	Geometric mean	Elasticity (a_i)[a]	MP[b]	VMP[c] (USh)
Naional level (Pooled data)					
Land (LAN)	ha	0.471	1.068	385.5	154,300
Labour (LAB)	MD/ha	98.8	0.4182	0.72	288
Pest control	USh/ha	16,690	0.0356	0.0004	0.16
Output (Y)	Kg	170			
Arua					
Land (LAN_1)	Ha	0.311	0.9687	548	219,200
Labour (LAB_1)	MD/ha	168.8	0.6500	0.68	272
Output (Y_1)	Kg	176			
Lira					
Land (LAN_2)	Ha	0.425	1.0808	363.7	145,400
Labour (LAB_2)	MD/ha	63.1	0.6208	1.41	564
Output (Y_2)	Kg	143			
Soroti					
Land (LAN_3)	Ha	0.560	1.1102	233.9	93,560
Labour (LAB_3)	MD/ha	87.9	0.5047	0.68	272
Capital (CAP_3)	USh	12,565	0.3991	0.004	1.6
Pest control	USh/ha	19,714	0.0606	0.0004	0.16
Output (Y_3)	Kg	118			
Pallisa					
Land (LAN_4)	ha	0.493	1.2723	673.6	269,440
Labour (LAB_4)	MD/ha	80.7	0.5001	1.62	648
Capital (CAP_4)	USh	8,885	0.3012	0.009	3.6
Pest control	USh/ha	13,645	0.1160	0.002	0.8
Output (Y_4)	Kg	261			

[a] From Table 1
[b] MP = Marginal productivity calculated using equations (8)-(11)
[c] VMP = Value marginal productivity, calculated by multiplying the MP by average rural market price for cowpea (USh 400)

districts, respectively. Since the returns per Shilling invested in implements is more than one in both districts, it is profitable for farmers to increase investment in implements such as ox-ploughs.

The VMP of pest control was USh 0.16 and 0.8 per USh increase in investment in pest control, in Soroti and Pallisa districts, respectively. This shows that in both districts, although the elasticity of production of inputs used for pest control is positive, the increase of investment in pest control by UShs 1 results in a less than UShs 1 increase in the returns to the farmer. This might be related to our observation during the diagnostic survey,that misuse of pesticide by the farmers was common (data not shown). In many cases farmers used low dosages, applied insecticides irregularly or untimely and used improper application methods such as sprinkling the pesticide instead of using sprayers. Besides, most farmers were not aware of the recommended application rates. This resulted in much wastage. Therefore the full potential of increased returns from the use of pesticides is not realised by most of the farmers, although some invest considerably in pest control.

Conclusions and Recomendations

In this analysis a Cobb-Douglas type of model was used to estimate the cowpea production functions in Ugandan agriculture using ordinary least squares regression. A number of parameter estimates which were generally consistent with the observed behaviour on farms in the study area, were derived for the cowpea production function model.

The returns to scale calculated in this study indicated increasing returns in cowpea production in Uganda especially in Pallisa district. Land and labour inputs had significantly positive elasticities in all the districts considered in this study, while capital and pest control inputs had significant elasticities only in Soroti and Pallisas districts where ox-cultivation and pesticides are extensively used. Also, land, labour and capital had favourable marginal productivities in cowpea production. Pest control inputs, however, had diminishing marginal productivity. This was attributed to the improper use of pesticides, due to wrong dosage applications coupled with poor application methods.

Based on the findings of this study it is recommeded that:

(a) The government should endeavour to restock the areas where there have been high losses of oxen due to civil turmoil, especially in the eastern region. The critical shortage of oxen is a major constraint to the crop development programme in the study area. Results of this study have shown that it is profitable (VMP > marginal input cost) for farmers to invest in ox-cultivation. Apart from increasing cropped land, the oxen can increase farm income from direct livestock and livestock by-products sales.
(b) Since crop production in the study area is done under low-input farming system which uses land and labour as the principal inputs and where land, labour and capital have favourable marginal productivities in cowpea production, farmers should allocate more land to cowpea and also use improved management practies. In the short run, increase in the area planted with cowpea will increase cowpea production, since land has the highest production elasticity compared to the other inputs and is not a limiting factor in most of the study area. Improvement of production technology through the use of ox-cultivation and the proper use of pesticides, will also in the long run increase cowpea production in the study area. The increasing returns to scale imply that, increased production of cowpea will increase farmers' incomes.

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