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Research Article

Analysis of Optimal Crop Enterprise Combination by Small Scale Crop Farmers in Kipkelion West, Kericho County, Kenya

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ABSTRACT

Optimal crop enterprise combination enables small scale farmers to earn the highest possible income under resource limiting conditions. Crop enterprise combination by small scale farmers in the study area has been sub-optimal and consequently, have been earning low annual gross margins, which is attributed to the knowledge gap in the nature of trade-offs made while making enterprise combination decisions. This paper examined the determinants of optimal crop enterprise combination by small scale farmers. The study was guided by the theory of the firm and descriptive and cross sectional research designs were adopted. The study drew a sample of 154 smallholder farmers through stratified random sampling techniques. The primary data was collected using a structured interview schedule and analyzed using descriptive and linear programming (LP). LP results revealed that the optimal crop combination was obtained when 0.82 and 0.87 hectares of maize and coffee are combined to give a gross margin of Kenya Shillings (KSh.) 241,810. The results further revealed that the total land and capital available for crop production was fully utilized under optimal crop enterprise combination while only 50% of available labour was utilized. Based on the results, this study recommend cultivation of 0.82 and 0.87 hectares of maize and coffee respectively to maximize farm incomes. Secondly there is need for policy makers both at national and county governments to formulate or review agricultural land use policies since land size under crops significantly affect optimal crop combination plan in the study area. Thirdly, there is need for small scale crop farmers to embrace intensive crop production technologies as land was found to be a limiting factor in crop production. Fourthly, the results on capital use imply that capital was a limiting factor of production in the study area. This study recommends that the financial institutions should provide agricultural credit that is tailored to maize and coffee production. Lastly, there is need to put in place measures by small scale farmers that would increase productivity and decrease TVC so as to increase GM. Such measures include use of high yielding crop varieties that are also resistant to pests and diseases.

Keywords: Small scale crop farmers; Optimal Crop Combination; Linear Programming

INTRODUCTION

Kenya is largely an agricultural country. About 80 per cent of Kenya's population lives in rural areas and depend on agriculture for their livelihoods. Estimations are that 75 per cent of this population is engaged in agricultural activities. The sector contributes up to 26 per cent of the Gross Domestic Product (GDP) [1]. and it is dominated by smallholders who account for about 75 per cent. Although agriculture is the most important in terms of economic contribution and livelihood generation, its productivity is largely declining in Kenya [2]. The smallholder farmers continue to suffer largely owing to production and marketing risks. Declining crop productivity impairs societal goals of improving food, income and nutrition security especially

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in rural areas of Kenya. Such impediments call for immediate measures to ameliorate the situation. Optimal crop enterprise combination is one of the potential strategies in sustaining agricultural productivity, and copping with marketing risks. It enables small scale farmers to earn the highest possible income under resource limiting conditions.

Combination of two or more crops in a farm has been practiced for several years in most parts of the world because of the benefits famers derive from these cropping systems. This is particularly the case in most parts of Africa, Asia and Central America [3]. Adoption of an optimal crop combination plan has been considered one of the most important means of increasing agricultural production, farmers' incomes and increasing food security in the world [4]. For example, adoption of optimal crop enterprise combination through 'Green Revolution' program in India saw the country not only becomes a self-sufficient country in food production and consumption but a net food exporting country.

Choosing an optimal crop enterprise combination in most of the agrarian continents like Asia and Africa has undoubtedly been one of the greatest challenges facing farmers due to the multiple objectives such as food security, cash requirements and profit maximization [5]. Decision making by smallholder farmers on optimal crop enterprise combination is further made complicated as land sizes continuously decrease and the available land face competing uses [6]. For example, large scale farmers could be interested in profit maximization whereas smallholder farmers could be interested in food security and risk minimization.

Optimal crop enterprise combination enables small scale farmers to earn the highest possible income under resource limiting conditions. Determination of optimal enterprise combination by small scale farmers has not been an easy task given that they have multiple goals. Deciding on the best crop combination can only be made if the information on optimal enterprise plan and the nature of trade-offs made while making such decisions is known and available. The government of Kenya has emphasized on crop diversification and value addition in agriculture. Some of the key areas of policy concern and strategy highlighted in Kenya Vision 2030 include catalyzing enhanced agricultural productivity, food security and income growth through crop diversification. In line with government policy, Kericho county has developed a strategic plan on promoting high-value crop and livestock enterprise (Kericho County),) [7]. In Kericho County, particularly Kipkelion West, Optimal crop enterprise combination has been identified as an important means of improving farm incomes. Optimal crop enterprise combination enables small scale farmers to earn the highest possible income under resource limiting conditions. Determination of optimal enterprise combination by small scale farmers has not been an easy task given that they have multiple goals. In spite of the potential benefits of optimal crop enterprise combination, deciding on the best crop combination can only be made if the information on optimal enterprise plan and the nature of trade-offs made while making such decisions is known and available.

Many studies have attributed low agricultural productivity to many factors including lack of use of new agricultural technologies, low education levels, inadequate information on optimal farm plans long distance to markets, limited access to credit facilities, inadequate extension services and lack of affordable agricultural credit. For example, For example, [8]. used the Logit model and found out that education, trade experience, level of information influence farmers cropping pattern in Thailand. A study by) [9]. on crop diversification as a small scale livelihood strategy within semi-arid agricultural systems near Mount Kenya showed that farmers can reduce their vulnerability to climate change by practicing crop diversification. The research showed that crop diversification does not only expand the extent of potential crops but also improves the ecosystem of agriculture that functions by building redundancy into the agricultural system by necessitating innovations in areas that has effects of climate vulnerability.

There is scarcity of studies focusing on optimal crop enterprise combination in Kenya hence there is lack of knowledge about the status of optimal crop enterprise combination. Farmers therefore end up using various local methods like trial and error, copying from progressive neighbouring farmers and from their personal experiences to address this problem. However, these methods do not give an assurance that optimal results will be obtained and thus they end up operating at the sub-optimal levels. This study, therefore, seeks to examine factors influencing optimal crop enterprise combination in Kipkelion West Sub-County. The results from the study would inform policymakers on the importance of optimal crop enterprise combination in agricultural productivity. The study would also determine factors influencing their decision making in optimal crop enterprise combination in a cropping system

Statement of the Problem

Optimal crop enterprise combination enables small scale farmers to earn the highest possible income under resource limiting conditions. Determination of optimal enterprise combination by small scale farmers has not been an easy task given that they have multiple goals. Deciding on the best crop combination can only be made if the information on optimal enterprise plan and the nature of trade-offs made while making such decisions is known and available. In Kenya and Kericho County in particular, agricultural crop enterprise combination/mix is at sub-optimal levels hence the small scale farmers earn low farm incomes. The farmers end up using various local methods like trial and error, copying from progressive neighbouring farmers and from their personal experiences to address this problem. However, these methods do not give an assurance that optimal results will be obtained and thus they end up operating at the sub-optimal levels. It is evident that the current annual crop enterprise combination is sub-optimal and therefore, small scale crop farmers earn a lower annual gross margin than the optimal combination for the Sub-County. Sub-optimal enterprise combination leads to decreased farm incomes. The above problem is because it's not known by the farmers how best they can combine their crops mainly maize, coffee and sugarcane using the available resources in order to maximize their farm incomes. This research provides

critical information on how the farmers can combine their crops in order to maximize their farm incomes given the limited resources.

METHODOLOGY

Research Design

The study used descriptive and cross sectional research survey designs. These two designs were preferred because they are exploratory, allow for comparisons and analysis of the research findings, and also enable the researcher to collect, summarize, present, evaluate and interpret the data in a simpler and more understandable form) [10]. Descriptive research design used to describe the characteristics of the population by measuring the frequency of the variables of interest in the study. The numerical data obtained from an interview schedule were also be used to analyse the socio-economic characteristics of small-scale crop farmers and optimal crop enterprise plan. Cross sectional research design allows for data to be collected at a single point in time over a short period of time. The design is suited for descriptive studies and for determining relationships between and among variables. It is also economical in terms of time and financial resources.

The Study Area

Location, Position and Size

The study was done in Kipkelion West Sub-County in Kericho County, Kenya. The Sub-County is one of the six Sub-Counties in Kericho County. It is located in the North Eastern side of Kericho Town and it lies between longitude 350 02' and 35° 40' East and between the equator and latitude 0 23' South with an altitude of about 1800m above the sea level. The sub county is bordered by four sub counties namely Kipkelion East to the East, Ainamoi to the South and Muhoroni to the West and Tindiret to the North-West as shown in Figure 3.1.

Sampling Procedure and Sample Size

The study used stratified random sampling procedure to obtain a sample of small scale crop farmers in the Sub-County. The Sub-County was stratified into four namely; Chilchila, Kunyak, Kamasian and Kipkelion which formed the first strata. The second strata were the locations in each ward. Random sampling was used to pick a location in each ward. In each location, proportionate sampling procedure was used to pick the small scale farmers for the study. A list of all the small scale farmers in each location was obtained from the Department of Agriculture office. The names of the farmers in the list was serially numbered and randomly ordered and picked using simple random sampling technique.

The required sample size for the small scale farmers for this was determined by using the following equation (1) for determining the sample size for a finite population [11].

$$n = \frac{NC^2}{C^2 + (N-1)e^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where n is the sample size, N is the population size (10,089), C is the coefficient of variation (which is 25%). e is the margin of error (which is 2%). By using the above formula, a sample of 154 sample units (small scale crop farmers) was obtained. Table 1 shows the number of small scale crop farmers' distribution per ward as a proportion of the total small scale crop farmers in the Sub-County. The random sample of small scale crop farmers in the Sub-County consisted of 31 small scale farmers in Kunyak, 54 in Chilchila, 35 in Kamasian and 34 in Kipkelion.

Data Types and Data Sources

This study used both primary and secondary data sources. Primary data was collected directly from the small scale crop farmer household heads through personal interviews. The primary sources of information that were gathered included the socio-economic characteristics, crop productivity (costs and returns) for maize, coffee and sugarcane over the past five years. Secondary information was collected by reviewing of literature from the Ministry of Agriculture (Crops Department) reports and other documents relevant to the study like published theses and economic journals, economic surveys, statistical abstracts, conference reviews, books, magazines, national and county development and strategic plans, National Bureau of Statistics publications, desktop literature, and the internet sources. This helped in obtaining information that had not been captured in primary data collection.

Table 1. Target population per ward and sample size

S/No.	Ward	Target Population	%	Sample size
1	Kunyak	2,030	20	31
2	Chilchila	3,518	34	54
3	Kamasian	2,265	23	35
4	Kipkelion	2,276	23	34
	TOTAL	10,089	100	154

Data Collection Instruments

A structured interview schedule was developed and used to collect data from small scale farmers in the study area through face to face interviews by the researcher. Secondary data was obtained from Ministry of Agriculture, books and other documents that were relevant to the study using document analysis form and the respondents were crops officers in the County and Sub-County.

Analytical Frameworks

Theoretical Models

This study adopted "The Theory of the Firm", which is the theory of production economics, and part of microeconomics. The theory deals with the production of goods from a set of inputs.The numerous decisions a firm makes is mainly concerned with making decisions that to maximize profits. The theory suggest that a firm produces goods only up to the point where we have marginal cost and marginal revenue equalizing each other and the factors of production that are used reaches a point where the marginal revenue product generated is equal to the marginal cost incurred in the use of the additional factor [12].

As the firm seeks to produce more output, it tries to reduce the unit cost of production as much as possible. The firm has to make a decision on desired output that has the cheapest combination of factors of production. These decisions that a firm makes can be understood better in the production function. Production function is an equation that shows the correlation between the amount of a product obtained and the amount of factor of production. This correlation can be expressed mathematically as shown in equation (2) as adopted from [13].

$$y = f(x_1, x_2, \ldots, x_n; k_1, k_2, \ldots, k_m). \quad \ldots\ldots\ldots\ldots\ldots (2)$$

Where, y denotes the amount of output produced. The firm is assumed to apply n variable factors of production; this means that the amount can be increased or decreased. In the equation, the amount of the first variable is taken to be $x1$ and so on. It is also assumed that the firm will apply m fixed factors; these are quantities that cannot be varied easily. The $k1$ are the first factors of the available quantity. The general rule is that there will be productive factors that are combined together to produce the same results. The problem of minimizing cost is finding the cheapest among them. The total cost of all various factors of production is termed as the cost of production and is expressed as shown in equation 3.

$$C = P_1X_1+P_2X_2+\ldots+P_nX_n+r_1k_1+r_2k_2+\ldots+r_n \quad \ldots\ldots\ldots\ldots (3)$$

Where C denotes the total cost of production, p1, p2, p3,..., pn, denotes the price of variable factors of production, X1,X2, X3, ..., X n denote variable factors of production, r1, r2, r3, ..., rn denotes the annual cost of owning and maintaining the fixed factor of production. The main objective of the producer is to maximize profit either by increasing the quantity of Y produced or by reducing the cost of producing Y. The production function shows the maximum amount of the goods that can be produced using alternative combinations of factors [14]. The profit-maximizing firm chooses both inputs and outputs to maximize the difference between total revenue and total cost as shown in equation 4. The firm will adjust variables under its control until it cannot increase profit further. Thus, the firm looks at each additional unit of input and output with respect to its effect on profit. MR = MC is the profit maximization rule. MR is the change in revenue resulting from a small change in output and MC is the change in cost resulting from a small change in output. The profit equation is as shown in Equation 4 and as adopted from [15]. The Total Revenue (TR) is the product of the total output (Q) and the price per unit (P) of the output as expressed in Equation 5 while the Total Cost (TC) is the sum of Total Variable Cost (TVC) and the Total Fixed Cost (TFC) as shown in Equation 6.

$$\pi = TR-TC \quad \ldots\ldots (4)$$

$$TR = P*Q \quad \ldots\ldots (5)$$

$$TC = TVC + TFC \quad \ldots\ldots (6)$$

Where π = Profit, TR = Total Revenue, TC = Total Cost, P = Price, Q = Quantity, TVC = Total Variable Cost and TFC = Total Fixed Cost.

Specification of Empirical Model

Linear programming (LP) was used to determine the optimal crop combination in maize; coffee and sugarcane crop farming system, and the maximum profits obtained was going to be compared with the calculated Gross Margins (GM) in monetary terms to determine the level of household income. It was also used to determine how the resources available could be combined in order to maximize profits through use of the optimal decisions that was obtained by linear programming. The technique is a common mathematical modelling technique that is used to solve optimization problems in which the objective function is optimized subject to various linear constraints [16].

Linear programming model as adopted from [17]. was used to determine the optimal crop enterprise combination for the three crops as specified in Equation 7. The three major structural parts of an LP technique, namely the objective function, resource constraints and non-negativity condition specified in Equation 7 that represents the objective function, Equation 8 represents resource constraint conditions while Equation 9 is the non-negativity inequality. The problem was to maximize the objective function (profit maximization) on the farm (from maize, coffee and sugarcane crop enterprises) subject to the resource constraints (cost of production) specified in the model.

$$\text{Max } Z_{ij} = \sum C_jX_j = C_1X_1 + C_2X_2 + C_3X_3 \quad \ldots\ldots (7)$$

Subject to:

$$A_{11}X_1 + A_{12}X_2 + A_{13}X_3 = B_1 \quad \ldots\ldots (8)$$

$$A_{21}X_1 + A_{22}X_2 + A_{23}X_3 = B_2$$

$$A_{31}X_1 + A_{32}X_2 + A_{33}X_3 = B$$

$$X_n \geq 0 \text{ for } n = 1, 2 \text{ and } 3 \text{ (non-negativity inequality requirement)} \quad \ldots\ldots (9)$$

Where, Zj is the objective function (Gross Margin) Cj is the net price per unit of activity j for j =1, 2 and 3, Xj is the level at which activity to be produced/ number of units of activity for j = 1, 2, 3), B1 is the amount of land available for crop enterprises X1, X2 and X3, B2 is the amount of labour available for crop enterprises X1, X2 and X3, B3 is the amount of capital available for crop enterprises X1, X2 and X3, and Aij is the amount of the activity i consumed by each unit of activity j subject to three

constraints which are land, labour and capital. The total gross margins in the model (Z) are the sum of gross margins for the three crop enterprises namely maize, sugarcane and coffee, C1 is the gross margin from maize, C2 is the gross margin from sugarcane and C3 is the gross margin from coffee. The total average net returns were calculated by deducting variable expenses from total average gross returns.

To determine the maximum value of a linear program for this study, Simplex method or approach was used and as adopted from [18].

RESULTS AND DISCUSSION

Table 2 shows results on gender, marital status, education level and main source of income. With respect to gender, results show that males were 87.8% while females were 12.2% of the small scale farmer households interviewed. The results illustrate a significant variation in the gender distribution among the small scale farmers.

Table2: Demographic Characteristics of the respondents.

Variable	Category	Frequency(N)	Percent
Gender	Male	129	87.8%
	Female	18	12.2%
Marital status	Single	1	0.7%
	Married	145	98.6%
	Widowed	1	0.7%
Education level	None	6	4.1%
	Primary	33	22.4%
	Secondary	84	57.1%
	College	19	12.9%
	University	5	3.4%
Main source of income	Farming	146	99.3%
	Other employment	1	0.7%

Results as shown in Table 2 on the marital status of the small scale crop farmers revealed that 98.6% were married while and equal percent of 0.7% were single and widowed respectively. This shows that the majority of the small scale crop farmers are married, an important factor that affects agricultural production.

Summary statistics results on education levels as shown in Table 2 shows that 4.1% of the household heads had no formal education while 22.4%, 57.1%, 12.9% and 3.4%had attained primary, secondary, college and university levels of education respectively. These results show that most of the farmers (95.8%) in the study area had formal education that could enable them make the necessary production decisions.

Further, results show 99.3% of the farmers reported that farming was their main occupation while 0.7% of them reported that other forms of employment was their main source of income. This current result on small scale family head's main occupation reveals that the majority of the farmers in the study area depend mostly on agriculture as the main source of livelihood.

Determination of Optimal Crop Combination

Table 3 of results show average productivity of maize, coffee and sugarcane over five year period. The results show that coffee has the highest gross margin followed by maize and sugarcane in that order.

Table3: Average Crop Productivity.

Crop	TR (KSh)	TVC (KSh)	GM (KSh)
Maize	175,000	43,000	132,000
Coffee	282,000	132,000	150,000
Sugarcane	229,600	101,600	128,000

Table 4 shows unit resource requirement against available resources by maize, coffee and sugar cane. One hectare of maize requires 110 Man Days (MD) and capital of KSh. 43,036, coffee requires 200 MD and capital of KSh. 132,000 while sugarcane requires 245 MD and capital of KSh. 150,000.

Table4: Unit Resource Requirement against Available Resources.

Resource	Resource requirement per hectare			Total Resource
	Maize	Coffee	Sugarcane	available
Land (Ha.)	1	1	1	1.69
Labour (MD)	110	200	245	512
Capital (KSh)	43,036	132,000	101,676	150,000

Table 5 of results shows optimal crop combination of maize, coffee and sugarcane using simplex method.

Table5: Simplex Method Results on Optimal Crop Combination.

		X1	X2	X3	S1	S2	S3	C
Cons train t	Cb P	136000	150000	128000	0	0	-Z	

Maize (X1)	136000	0.82	1	0	0.34	0	0	1.48	0.82
Slack (S1)	0	0	0	0	84.74	1	0	-66.5	6.35
Coffee (X2))	150000	0.87	0	1	0.66	0	0	0.48	3.49
Max Z	241810.42	0	0	17218	0	0.16	Z +129235		

The value of the objective function (gross margin maximization) in the table of results is presented as Z = 241,810.42 which mean that the optimal crop combination plan give a maximum gross margin of KSh 241,810.42. The variables that are present in the basis are X1 = 0.82, X2 = 0.87 and S3 = 0; representing the area under maize, coffee and sugarcane respectively. The slack variable S3 replaced sugarcane (X2) because it contributed the least to the total GM which was being maximized. Therefore, from the results, an optimal farm plan or crop enterprise combination plan for the small scale crop farmers in the study area is to combine 0.82 with 0.87 hectares of maize and coffee respectively in order to obtain a maximum Gross Margin of KSh 241,810.40 per year. All the available land for crops is fully utilized as this was the average area of land available for crop production.

Further, results in Table 4 indicate that no production of sole crop enterprise would maximize the gross margins. This finding agrees with the findings [19]. that of all the sixteen crops studied, no sole crop would be optimal for profit maximization but rather a combination of more than one crop. The result of this study also agrees with the findings by) [20]. that revealed that mixed cropping decisions yields higher revenue and provide for efficient use of farm resources per hectare compared to sole cropping activities. In the field of capital utilization, the optimal crop enterprise plan used up all (100%) of the capital available. This could imply that capital is a limiting factor in crop production in the area as all what is available is utilized. However, in terms of labor utilization, only 51.2% of the available labour was utilized in the optimal crop enterprise plan. This indicates that there is surplus labour in crop production in the study area hence it is not a limiting factor in production. However, there could be labour peak periods in the course of production as demand for labour is not uniformly spread over the year.

CONCLUSIONS

Descriptive statistics results showed that the mean age of the small scale crop farmer household heads was 46 years while 87.8% of the family heads were males while the females were 12.2 %. 98.6% of the family heads interviewed were married with an average family size was 5 persons. The average number of years of experience in farming was 17 years. The study results further revealed that farmers who had not obtained any formal education was 4.1 %, those with primary level was 22.4%, with secondary education was 55.1% while those with tertiary level of education was 18.4%. 99.3% of the farmers depended on agriculture as their main source of livelihood while 0.7% of the farmers had other occupations as their main source of livelihood.

It can be concluded from this study that the gross margins would be maximized if the small scale crop farmers cultivate 0.82 hectares of maize and 0.87 hectares of coffee. This would give a maximum gross margin of KSh 241,810. Further, land and capital are limiting factors of production as the total land and capital available for crop production were fully utilized under optimal crop enterprise combination. However, labour is in excess supply as only 50% of the available labour was utilized. This study also recommends that small scale farmers should diversify their crops as the study revealed that neither sole crop farming nor the current level of crop combination was optimal.

The study recommends the following strategies for strengthening crop diversification amongst the smallholder farmers. (i) This study recommend that small scale farmers should diversify their crops as the study revealed that no sole crop farming nor the current level of crop combination was optimal. The crop combination plan that should be adopted is cultivation of 0.82 hectares of maize and 0.87 hectares of coffee, (ii). There is need for policy makers both at national and county governments to formulate or review agricultural land use policies. There is need to regulate land fragmentation since land size under crops significantly affect optimal crop combination plan in the study area (iii). This study recommends that the financial institutions should provide agricultural credit that is tailored to maize and coffee production. (iv). this study recommend the use of labour intensive technologies in production of maize and coffee by the small scale farmers in order to utilize the excess labour.

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