THE EFFECT OF SOIL CONSERVATION ON OPTIMAL CROPPING PATTERNS IN KERICHO DISTRICT, KENYA

Kipsat, M.J., Maritim, H.K., Korir, M.K., Serem, A.K., Nyangweso, P.M.,*
Dept. of Agricultural Economics and Resource Management,
Moi University, P.O. Box 1125, Eldoret, Kenya.
Email address: mjkipsat@yahoo.com

Okalebo, J.R. Kisinyo,
Dept. of Soil Science, Moi University, P.O. Box 1125, Eldoret, Kenya.

Oyasi S.S.
Ministry of Water and Irrigation, Siaya District.

Abstract

Production and consumption activities are directed by multiple and conflicting goals. The objective of this study was to determine the changes in optimal resource utilization patterns arising from soil conservation. A purposive sample of 150 farmers was selected from three administrative divisions of Kericho district. Questionnaires were used to collect primary data needed for analysis. Pre-emptive goal-programming model was used to determine the optimal cropping patterns. Results showed that out of 20 basic cropping activities identified in the study area, 20% and 10% entered the optimal cropping program in conserved and eroded areas respectively. Shadow prices for fully utilized resources indicated that cost of production decreased if additional units of the fully utilized resources were used. The non-fully utilized resources included land and hired labor. In conclusion, it was evident that given the present structure of available resources, average households in study area could not fully meet their household goals.

Keywords: Goal-programming, optimal cropping patterns, soil conservation

Introduction

Land degradation is a threat to sustainable production in agriculture-based poor economies. Farm families integrate production and consumption activities and a large proportion of agricultural output is consumed. Production and consumption activities are directed by multiple and conflicting goals operative in the system. Smallholder farms in many developing countries represent 95% of the total food crop farms and contribute 90% of total food crop output (FAO, 2004). Small-scale farms are known for low level of operation, illiteracy of operators and labor-intensive production (Okuneye and Okuneye, 1988). According to FAO (2004), 75% of labor demands in many African countries originate from the family.

Kenya's agricultural sector contributes about 25% of GDP, 60% of total earnings, 45% of government revenue and employs 80% of labor force while accounting for 80% of rural incomes (RoK, 2002). Soil erosion is a threat to agricultural production in many parts of Kenya (Kilewe and Thomas, 1992). Other constraints to growth in the agricultural sector include: poor farming practices and choices of enterprises, policy related disincentives for technology adoption, underdeveloped credit markets and low returns to farming (Feder *et al*., 1985).

Soil conservation was introduced in Kenya's Agriculture sector in the 1930s (Anderson, 1984). In 1938, a soil conservation service was formed. Soil conservation funding was advanced through African Land Development Board and Swynnerton Plan of 1950's. Coercive soil conservation was practiced (Tiffen *et al.*, 1994). Kenyans later resisted soil conservation as they considered it part of a colonial plan to distract them from struggling for freedom (Thomas *et al.*, 1986; SIDA, 1993). After independence in 1963, soil conservation was given little attention as it was seen as a symbol of colonial oppression and colonial legacy (Ericksson, 1992; SIDA, 1993). Soil conservation structures were either destroyed or neglected. In 1974, soil conservation was reintroduced due to the negative effects of soil erosion in Kenya's agricultural sector (Pretty *et al.*, 1995). A Permanent Presidential Commission on Soil Conservation and Afforestation was formed in 1981 to create awareness about the need for conservation (Anyieni, 1986; Kilewe and Thomas, 1992).

Kericho District slopes westwards with a rough terrain and many rivers and streams. Climate is Highland Sub-Tropical with high and well-distributed rainfall and no real breaks between short and long rains. Mean annual rainfall ranges between 1000 mm and 1600 mm. The District is subdivided into 4 main agro-ecological zones namely Upper Highland, Lower Highland, Upper Midland and Lower Midland. Many organizations have done a lot of research and generated information on ability of soil conservation measures to provide technical solutions to soil degradation problems in the study area. Raising and sustaining agricultural productivity however is still a problem. A review of the existing body of knowledge reveals no studies on the economics of soil conservation in the study area (Kipsat, 2006). Lack of such information may mean that farmers are not sure whether long-term investments in soil conservation are justified (Shiferaw and Holden, 1997). The objective of this study was to determine the effect of soil conservation on farmers' optimal cropping and resource allocation patterns.

Methodology

Theoretical and Empirical Framework of Study

The farm household model assumes that farmers have many objectives focusing on welfare or profit maximization (Upton, 1987; Ellis, 1988; Scherr, 1995). Studies in sub-Saharan Africa (Upton, 1987; Mokwuye *et al.*, 1996) reveal that in an effort to maximize utility, most farm households pursue a combination of objectives: securing provision of food and other subsistence needs, earning a cash income for purchase of outside goods and services, saving or accumulation of resources to meet future planned needs and emergencies, risk aversion, long-term security, and achievement of community status.

The basic structure of agricultural firm model is an adaptation of traditional agricultural firm models that assume inseparability of production and consumption systems (De Janvry *et al.*, 1992 and Delforce, 1994). Farmers in this study were assumed to have three optimization goals namely: food security for the family throughout the year; accumulation of monetary income; and minimum use of hired labor or efficient use of family labor. Farmers' goals were assumed to be subject to limitations imposed by specific household resource constraints. The theoretical household model deal with optimization of goals and optimization implies efficiency (Baumol, 1977). In multi-product firms, the equimarginal principle is the neoclassical economic efficiency criterion for resource allocation.

Goal Programming (GP) technique is used to optimize a multi-objective problem that balances trade-offs in often conflicting unequal goals. Ranking and weighting various goals and their sub-goals based on their importance establish a priority structure that helps to deal with all goals that cannot be fully and/ or simultaneously achieved. More important goals are achieved first at the expense of less important ones. The decision-maker cannot achieve every goal to the desired extent, thus he attempts to achieve a satisfactory level of all goals rather than optimal solution for a single goal. GP involve minimizing deviations from established goals within the set of constraints. The objective function is minimization of a sum of the deviations based on relative importance assigned to each deviation. The general linear GP model with *m* goals is given as:

$$\text{Minimize } Z = \sum_{i=1}^{m} \sum_{r=1}^{k} P_r \left(W_i d_i^{-} + W_i d_i^{+}\right)$$

Subject to the linear constraints

$$\sum_{j=1}^{n} a_{ij} X_j + d_i^{-} - d_j^{+} = b_i;\ i = 1, 2, \ldots, m \qquad \text{equation 1}$$

$$\text{and } X_j = d_i^{-},\ d_j^{+}, \geq 0 \text{ for all i and j}$$

$$d^{-} + d^{+} = 0$$

Where, Z is sum of deviations from all desired goals having *m* goal constraints and *n* decision variables, X_js. The W_i's are non-negative constraints representing the relative weight for deviational variables d_i, d_j for each goal constraints. P_r's are pre-emptive priorities assigned to the sets of goals that are grouped together in problem formulation. The a_{ij} are constants attached to each decision variable and the b_i's are the right hand side values (goals) of each constants.

To achieve multiple goals according to their importance, pre-emptive priority factors P_1, P_2,…, and so on is given to a goal deviation in formulation of the objective function to be minimized. P's do not assume numerical values but are a convenient way of indicating that one goal is more important than another. Priority ranking is absolute and the priority factors have the relationship of $P_1 >> P_2 >> \ldots >> P_k >> P_{k+1}$...., where >> means more important than. This means, $P_j >> nP_{j+1}$ (j =1, 2,…, K). Where n is a very large number.

A lower-priority goal will never be achieved at the expense of a higher priority goal. Two or more goals however may be assigned equal priority factor.

The objective in this study was to determine the farmers' optimal crop enterprise combinations that are able to meet a set of household objectives. The main objectives pursued by households in the study area were assumed to be: to provide adequate food to ensure at least minimum calorie for the household throughout the year; to earn adequate monetary income to at least meet minimum household financial needs and; to maximize utilization of family labour through minimum use of paid labour. The production systems were said to be optimal and sustainable only if they were able to provide adequate calorie intake for family throughout the year and to produce adequate monetary surplus to allow the household to acquire goods that were not being produced on the farm.

Farmers provided the prioritisation of objectives and pre-emptive weights. Pre-emptive weights were attached to these objectives based on the farmers' ranking. Indicators of sustainability and the deviational variable(s), d^- and d^+, were derived from the household characteristics.

The crop activities in model included: maize/tea; coffee/cotton/maize/kales; wheat/maize/pyrethrum; millet/cotton/coffee; tea/coffee; pineapples/coffee; tea/Pineapples; maize/wheat/millet/beans; wheat/maize/tea; cotton/coffee/pepper; maize/sunflower/pyrethrum; pyrethrum/tea/tomatoes; millet/maize; maize/beans; pyrethrum/sunflower/pineapples; millet/kales/maize/beans;

maize/wheat/beans; pineapples/pyrethrum/wheat; maize/sunflower/tea; sorghum/tomato/maize/cotton. Table 1 was the goal function structure of the basic goal-programming model.

Table 1: Objective Function Structure of a Basic Goal Programming Model

Farm family Production Objective	Goal Statement achievement	Goal Function Statement: to minimise	Goal function deviation variable	Priority Level	Pre-emptive Weights
(1) Farm household food security	i. Minimum maize intake	Underachievement	d^-	1	4
	ii. Minimum millet intake	Underachievement	d^-	1	4
	iii Minimum bean intake	Underachievement	d^-	1	4
	iv. Minimum wheat intake	Underachievement	d^-	1	4
(2) Limited labour cash expenditure	(i). Specified level of expenditure on labour	Overachievement	d^+	4	1
(3) Net farm income	i. Desired level of farm income	Underachievement	d^-	3	1
(4) Nutritional well-being	i. Minimum calorie intake	Underachievement	d^-	2	3
	ii. Minimum protein intake	Underachievement	d^-	2	3

Source: Results of Ranking and Weighting of Goals in this Study, 2003

Sources of Data Collected and Sampling Design

This study made use of primary and secondary data. Primary data was collected from farmers. Secondary data was obtained from publications, books and reports from research institutions. The indicator for adequate caloric intake came from WTO/ FAO adequate human caloric intake recommendations (FAO, 1974, 2004; Hamilton and Whitney, 1982; Goldman, 1994). The monetary income indicator corresponded to a minimum of 75% of the average household expenditure associated with the smallholder farmers in the study area. The labour saving indicator was represented by the desired level of cash expenditure on paid labour by smallholder farmers in the study area.

Purposive sampling was adopted in selecting respondents from three divisions: Londiani, Kipkelion and Sigowet of Kericho District. At least thirty households were selected from each division and data was collected from all soil conservation points in which 150 respondents provided data for this study.

Data Collection and Analysis

The data collection exercise was done between October and December 2003. Ten enumerators were chosen from each division and trained for the enumeration exercise. Questionnaires were pre-tested with a random sample of 40 farmers in Ainamoi Division, Kericho District. The questionnaires were orally administered to the respondents by the enumerators. Each questionnaire was first examined and assessed for reliability of data content in order to justify the content's inclusion in data analysis in this study.

Comprehensiveness and consistency of responses were used as selection criteria. The Linear Interactive Discrete Optimization (LINDO) software package was used to solve the pre-emptive resource allocation and multiple household goal attainment-programming problems.

Results and Discussions

The farmer's priority ranking showed that food security in terms of adequacy was first. Food security in terms of balanced diet was second. Accumulation of monetary income and limited expenditure on paid labour, through efficient utilization of family labour, were third and fourth respectively. Cost minimization was the underlying behavioral principle guiding farmers in resource allocation decisions. Out of 20 basic activities included in the model, 4 (maize/bean; maize/beans/millet; millet/maize/wheat and maize/sorghum/beans) entered the program in areas where soil conservation was practiced. Two cropping activities (maize/bean and maize/beans/millet) entered the programme in farms where soil conservation was not practiced. Table 2 presents results of pre-emptive goal programming that was constrained to use minimum cost possible to yield the minimum household food requirements. The program value or cost that would be incurred for the optimum farm plan to be executed was kshs. 64851.60 ($900.7).

Table 2: Crop Activities and Acreages in Conserved and Degraded Areas

Basic Cropping Activity	Acreage Allocations (Acres)	
	Conserved Soil	Degraded Soil
Maize/Beans	0.4	0.9
Maize/millet/beans	0.1	0.2
Maize/beans/tea	3.0	-
Maize/wheat/beans	2.35	-

Source: Summary Computer Printout Results of Goal Programming Model

The results above showed that the four enterprise combinations that entered the program in farms with conserved soil were maize/bean/tea (3 acres), maize/wheat/beans (2.35 acres), maize/beans (0.4 acres) and maize/millet/beans (0.1 acres). Two enterprise combinations, maize/bean and maize/millet/beans with acreage allocations of 0.9 and 0.2 acres respectively entered the pre-emptive goal program in degraded farms. Soil degradation affected resource requirements in that more land was needed to meet household production and consumption goals.

All resources except land were fully utilized in conserved areas. Planting and harvesting periods in the study area were associated with shortages of labor and most family members worked on the farm. Labor problems were severe in farms where soil conservation was practiced. As expected, more frequent farm household allocation decisions are made about labor than about all other resources combined. The problem of labor was being addressed by use of catchment approach to soil conservation. In this approach labor from several households was pooled and used to conserve soil in one region or farm at a time. The development of credit markets and government and NGO subsidies go a long way in addressing the problem of capital constraints. Table 3 provides summary results for resource allocations and use patterns among the sampled households in the study area.

Table 3: Household Resource Allocation and Use Patterns in the Study Area

Resource	Use Status in Degraded and Conserved Farms	Slacks for Degraded and Conserved Soil	Shadow price (MVP)
Land	Fully utilized (Not fully utilized)	None (5.825 acres)	20.8 (-)
Period 1 (March- June) family labor	Fully utilized (Fully utilized)	None (none)	1.45 (2.1)
Hired labor for period 1	Fully utilized (Fully utilized)	None (none)	1.6 (2.8)
Period 2 (Aug-Nov) family labor	Fully utilized (Fully utilized)	None (none)	0.7 (0.5)
Period 2 (Aug-Nov) hired labor	Not fully utilized (Fully utilized)	44.65 man-days (none)	- (2.2)
Cash paid labor	Not fully utilized (Fully utilized)	$38.2 (none)	-(2.4)
Cash on material inputs	Fully utilized (Fully utilized)	None (none)	2.2 (19.4)

Source: Computer Printout of Goal Programming Model

The figures in brackets in table 3 above are associated with farms with degraded soils. Resource utilization patterns showed that land, family and hired labor during period 1, family labor for period 2, and cash on material inputs were fully utilized in arriving at the optimal solution to the goal-programming problem in degraded farms. The non-fully utilized resource in conserved farms was land (5.825 acres) while hired labor for period 2 (44.65 man-days) as well as the cash paid labor ($38.2) was slack in degraded farms. Slack resources refer to factors of production that were in excess of the actual needs of the household in the specified period. The shadow prices for the fully utilized resources in degraded farms were $ 20.8, 1.45, 1.6, 0.7 and 2.2 for land, period 1 family labor, period 1 hired labor, family labor for period 2 and cash on material inputs respectively.

The shadow prices for the fully utilized resources in conserved farms were family labor period 1($2.1), hired labor period 1($2.8), family labor period 2($0.5), hired labor period 2 ($2.2), cash paid labor ($2.4) and cash on material inputs ($19.4). The shadow prices for the fully utilized resources indicate the decrease in cost of production if additional units of such resources were used. This meant that farmers practicing soil conservation would benefit from additional units of labor and capital. Table 4 gives the results of marginal opportunity cost of non-basic activities in the study area.

Table 4: Marginal Opportunity Cost of Non-Basic Activities

Non-Basic Activity	Marginal Opportunity Cost (MOC) in kshs ($)
Maize/tea	36724.60 (510.06)
Millet/cotton/coffee	17963.50 (249.49)
Pineapples/tea	24260.40 (336.95)
Maize/sorghum/beans	24819.70 (344.72)
Maize/sunflower/pyrethrum	3983.40 (55.32)
Wheat/maize/pyrethrum	27704.80 (384.79)
Sorghum/tomatoes/cotton	48316.00 (671.06)
Beans/wheat/tomatoes	1926.90 (26.76)
Tea/coffee	6813.70 (94.63)
Wheat/maize/tea	6886.50 (95.65)
Pineapples/coffee	30967.70 (430.11)
Maize/ wheat	18256.80 (253.57)
Sorghum/tomatoes/cotton	48316.00 (671.06)
Coffee/cotton/maize/kales	39129.90 (543.47)
Pineapples/pyrethrum/wheat	12354.20 (171.59)
Millet/beans,	9816.70 (136.34)

Source: Summary of Computer Printout Results in this Study

MOC indicated the amount by which the program value would increase if any non-basic activities (not currently in the system) were introduced into the program. Optimal production cost would increase by the margin equal to MOC value of excluded activities. Table 4 showed that sorghum/tomatoes/maize/cotton had the highest MOC of kshs 48316($671). Beans/wheat/tomatoes had lowest MOC of kshs 1926.9 ($26.8).

Annual family food supply depends on productivity of land, labor and variable capital inputs, adoption of technologies and favorable climate. Others are government policies, laws, regulations and institutional environment. Family labor was allocated to farm production, off-farm wage employment and leisure. Accumulation of cash income goal targeted maximization of net family earnings. Financial constraints facing farmers limited purchase of additional inputs and prevented long term investment and generation of physical capital.

Summary and Conclusions

Optimal allocation patterns depicted that soil conservation improves land, labor and capital productivity. More enterprise combinations entered the program in conserved than in degraded areas. The allocation patterns indicated inefficient use of resources among farmers who did not practice soil conservation. Some resources (land, labor and capital) were not fully utilized. Except for land, farmers who conserved soil used resources efficiently. Given the available resources farmers could not fully satisfy their production goals.

Recommendations

Mixed cropping pattern, mainly cereal-legume based, should be promoted since they greatly contribute to household income and food security goals. Suitability of cropping patterns should be assessed in terms of effect on soil stability and erosion risk. High and rising population pressure has caused people to encroach into forests and wetlands in the region. Lands earmarked for forest and grazing had been converted into cultivation due to the increasing demand for land. Settlement schemes subdivision and allocation was done without proper land use planning. Government policies on land use planning should therefore be implemented in the study area.

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