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Farm Level Economic Analysis of Soil Erosion Control in Tobacco Lands in the Hanguranketha Area

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ABSTRACT. *The effect of soil loss on yields of tobacco and two alternative crops is estimated by subjective elicitation method. This information is incorporated to a linear programming model to study the impact of four soil erosion control levels on the farm economy. Although tobacco is widely grown in the study area, when soil loss is restricted to soil loss tolerance value, tobacco does not appear in the optimal solution. Instead, the optimal solution suggests to grow carrot with bench terraces (0.47 ha) and carrot without any erosion control measures (0.52 ha). When the model is changed to realistic situations i.e., when soil loss restriction is relaxed and a little amount of initial capital is allocated, tobacco without erosion control appears in the optimal solution. As the extent of tobacco in the optimal solution increases, net returns show a decreasing trend. Thus, results reveal that the low capital situation together with other institutional factors force farmers to grow tobacco, and growing tobacco further impoverishes the farm economy. The introduction of an external flow of capital, probably in the form of credit, for alternative crops is suggested to break this vicious cycle.*

INTRODUCTION

Tobacco is a highly erosive crop cultivated in the hill country area of Sri Lanka with the supporting services provided by the Ceylon Tobacco Company (CTC). Tobacco cultivations are located in the upper Mahaweli watershed which drains to a series of reservoirs important to the economy of the country. Land degradation is one of the most crucial environmental problems in Sri Lanka and soil erosion is considered to be the major cause of land degradation (Norad, 1990; NARESA, 1991). Thus, soil erosion control in tobacco lands is of utmost importance from the watershed management point of view.

The CTC supplies credit facilities, inputs, extension services and a guaranteed market for cured tobacco. Although there are less erosive crops such as vegetables, which can be grown in tobacco lands, these crops face obstacles such as lack of an assured market, high price fluctuations, perishability and lack of storage capacity and comparatively poor institutional support. Given the monopsonic set-up of tobacco marketing, the price received by tobacco farmers is not competitive. However, the assured market, strong institutional support, and lack of economically viable alternative ventures in the study area force farmers to grow this erosive crop, despite the fact that they are aware of the environmental consequence of growing tobacco (Gunatilake, 1990).

The introduction of the Soil Conservation Act in 1951, incorporation of soil conservation in the post-war development proposal and establishment of soil conservation division under the Department of Agriculture are some of the steps taken towards curtailing soil erosion in the early 1950s. In addition, several subsidy programmes for soil conservation were introduced at different times. As accepted by many researchers all these attempts have achieved only limited success and soil erosion continues at a high rate (Wickramasinghe, 1989; Stocking, 1986: Thiruchelvam, 1989; Gunatilake, 1990). Moreover, the macro-economic policy frame of the country was changed in 1977, giving more emphasis to the market forces and presently there is limited scope for providing a subsidy or spending the scarce resources on soil conservation promotion activities. Therefore, farm level economic analysis is particularly germane in this context as it could provide a farmer with the type of information he needs to assess the economic rationale for adopting different soil erosion control practices.

In general, farm level economics of soil conservation had been given a low priority except as it was related to externalities in conventional economics during the sixties and seventies. One reason for this apparent lack of interest in the subject was the view that conservation of soil resource has little or no impact on agricultural production, in the short run, given the modern technology. It is noteworthy that this perception is no longer accepted by the intellectuals who deal with this subject. The rising energy cost all over the world and the consequent price increase of modern inputs, the pollution caused by the agro-chemicals applied and eroded soils have reemphasized the importance of farm level economics of soil conservation.

Most farmers usually look at soil conservation from a business perspective as they have to survive in a competitive market and often struggle to meet their basic needs. Although they may be concerned about the social cost of soil erosion, their decision to adopt soil conservation practices is dominated by the economic impacts of those practices on his farm business (Lovejoy *et al.*, 1986).

Linear programming models have been widely used to model conservation decisions. Compared to budgeting and regression methods, linear programming models are preferred because they allow to incorporate the relationships between soil loss and crop yield and also farmers' time preference into the model (Seitz and Swanson, 1980). Moreover, these models allow to introduce soil loss tolerance value as one of the constraints to the profit maximizing objective. Following the above discussion the specific objectives of the study were:

i. to quantify the economic impact of soil loss on productivity of tobacco and two other alternative crops; and

ii. to incorporate the estimated impact of soil loss on crop yields into an optimization model to examine the impact of four different methods of soil erosion control on farm economy.

Theoretical background

Soil conservation either maintains or improves the crop yield. Soil fertility that governs the yield is a function of many variables and information with respect to the relationship of these variables to crop yield is either not very precise or not available (Segarra and Taylor, 1987). A simplification must, therefore, be made and focus has to be placed on variables which are affected directly by soil erosion and which in turn affect crop yields. Top soil depth can be related to crop yield in this connection as previously shown by Burt (1981), McConnell (1983) and Segarra and Tailor (1987). The change of top soil depth in a farm over time can be expressed by the following equation:

$$X_{t+1} = X_t + SF_t - SL_{it} \qquad (1)$$

where,

X_t the top soil depth at time t

SF_t = the soil formation in time t, and

SL_{it} = the soil loss under ith conservation level in time t

The Mitscherlich Spillman production function was found to be appropriate to estimate the relationship between crop yields and top soil depth (Segarra and Taylor, 1987).

$$Y_t = a + b(1 - R^{X_t}) \qquad (2)$$

where,

Y_t = the crop yield at time t,

a = the constant representing the yield theoretically obtainable from the sub soil,

a + b = the asymptotic value of crop yield when $\lim X_t \to \infty$,

R = the constant ratio of the marginal product of X_{t-1} th top soil depth to the marginal product of X_t th top soil depth

If current top soil depth and soil losses under different erosion control methods are known, top soil depth at the end of every year can be estimated. The impact of soil loss on crop yield under different conservation practices can thus be captured by applying calculated top soil depths in equation 2.

As an economic agent, a farmer's behaviour towards the use of soil conservation practices is largely determined by the impact of these practices on his net revenue. Net revenue can be defined as:

$$NR_t = P_{yt}Y_t - \Sigma^n_{i=1} P_{it}Q_{it} - C_{it} \qquad (3)$$

where,

NR_t = net revenue per ha per year at time t,
P_{yt} = the price of the product at time t,
Y_t = the quantity produced per ha at time t,
P_{it} = the price of the ith input at time t
Q_{it} = the quantity of the ith input at time t,
C_{it} = the cost of ith conservation practice at time t,

Some costs and benefits of soil conservation occur over time. A sufficiently long time period should be considered to include these costs and benefits and these should be discounted using an appropriate time preference to bring these costs and benefits to a common time period so that comparisons are possible. This problem can be formulated as a linear programming problem as follows:

$$\text{Max; } Z = NR_t(1+r)^{-t}$$

$$\text{St; } g_i(x) <= b_i$$

where,

$g_i(x)$ are the activity levels and
b_i are the supply levels

METHOD

The functional relationship between the top soil depth and crop yields (equation 2) was developed using subjective elicitation of the relationship through a survey of knowledgeable individuals. The questionnaire for subjective elicitation was developed based on the Segarra and Tailor's (1988) work. A few knowledgeable tobacco-vegetable farmers, Agricultural Instructors working in the area and field Instructors of the CTC were interviewed using the questionnaire.

Top soil depths were measured in randomly selected sixteen plots in the area and the average value was used as an initial condition. Soil losses with and without soil conservation practices under tobacco, carrot and capsicum estimated by the Land and Water Use Division, Department of Agriculture, were used to calculate the top soil depth in subsequent years.

The cost of production and average price data were gathered from Cost of Cultivation Reports of the Department of Agriculture. These were supplemented with survey data when some of these data were not available. Capital cost of soil conservation structures and their maintenance costs were obtained from the CTC and the Soil Conservation Division of the Department of Agriculture. A ten year time horizon was considered for the analysis, and costs and benefits were discounted using different discount rates.

Four different erosion control levels, namely, no conservation measures, Lock and spill drains, Bench terraces and Stoned terraces were considered for the analysis. With these different soil conservation levels twelve activities were considered and they are as follows.

T_1 = Tobacco without conservation
T_2 = Tobacco with bench terraces
T_3 = Tobacco with lock and spill drains
T_4 = Tobacco with stoned terraces
C_1 = Carrot without conservation
C_2 = Carrot with bench terraces
C_3 = Carrot with lock and spill drains
C_4 = Carrot with stoned terraces
CP_1 = Capsicum without conservation
CP_2 = Capsicum with bench terraces
CP_3 = Capsicum with lock and spill drains
CP_4 = Capsicum with stoned terraces

Capital, labour and land constraints were included in the model. Land was restricted to one ha and Rs. 35,000/- were allocated as the initial capital. Labour constraint was set at 14 family labour days per week. In addition to these constraints annual soil loss of each activity was also considered as a constraint and soil loss was restricted to the soil loss tolerance value (10 mt/ha/year). A ten year time period was considered. The differences between discounted costs and benefits at the end of each year were transferred to the next year using transfer rows. A sensitivity analysis was performed for labour, capital and the level of soil loss tolerance. The analysis was performed for tobacco green leaf producers and producer curers (who produce and cure tobacco), separately.

RESULTS AND DISCUSSION

Table 1 describes the predicted percentage yield changes of tobacco, carrot and capsicum under different conservation practices over a 10 year period. It is clear that the highest yield reduction with no soil conservation is predicted for tobacco while carrot will have the least yield reduction under the same situation. All three soil conservation practices are capable of reducing the soil loss and associated yield loss to a considerably low level.

Table 1. Percentage crop yield losses under different soil erosion control measures over a ten year period.

Crop	Without conservation	Lock & spill drains	Bench terraces	Stoned terraces
Tobacco	24.4%	2.4%	1.6%	0.7%
Carrot	4.6%	0.5%	0.5%	0.2%
Capsicum	9.75%	2.2%	0.7%	0.5%

The optimal solution of the LP model with average annual soil loss equal or less than 10 mt/ha/yr for tobacco green leaf producers gives the following activity levels with a net return of Rs. 128,168/- under a 10% discount rate.

C1 (Carrot with no conservation) = 0.477 ha
C2 (Carrot with Bench Terraces) = 0.522 ha

This suggests that among the crops studied, carrot gives the highest returns with an acceptable level of soil loss. More importantly, tobacco does not appear in the solution suggesting that cultivation of tobacco is not as profitable as carrot. Further, since soil loss is restricted to 10 mt/ha/yr, results suggest that tobacco cultivation cannot be carried out within the acceptable level of soil loss.

In the optimal solution, land, capital and soil loss constraint.are binding. Dual values of these constraints and their right hand side ranges are given in Table 2. Dual value of land indicates that the shadow price of land is Rs. 88,829/- ha. Dual value of soil loss suggests that if one more mt of soil is allowed to be eroded the net returns per ha increases only by Rs. 434/-. Therefore, although not much, there is an incentive for farmers to cultivate carrot with higher soil loss than that is allowed in the model.

Table 2. **Dual values and right hand side ranges of the optimal solution.**

Constraint	Dual value	Right hand Min	Side range Max
Capital	1	22758	None
Land	88829	0.555	1.417
Soil Loss	434	2.70	18.0

Right hand side values of land and soil loss suggest that the solution is fairly stable. This is very important given the higher variability of soil loss and holding sizes among the farms in the study area. Capital constraint is also binding and as revealed by the minimum right hand side value, initial capital could have been reduced up to Rs. 22,758/- with out changing the optimal solution.

The optimal solution suggests to cultivate 0.477 ha of carrot without any conservation and 0.522 ha of carrot with bench terraces. The solution seems to be practical given the topography of the area, since there are slopey lands and valleys in the area. Farming can be done most profitably by allocating the slopey part of the lands to cultivate carrot with bench terraces and the rest, if not very slopey, to grow carrot without conservation. However, in cases where the entire farm land is slopey, this solution may not be practical.

The same model was fitted for the barn owners who cure tobacco. Curing gives higher net returns for barn owners since it increases returns by 100% (curing increases the total cost only by 63.5%). The same result was obtained in this model suggesting that even though barn owners get higher returns compared to green leaf producers, tobacco does not give the highest returns when the soil loss is restricted to the tolerance level of 10 mt/ha/yr.

Sensitivity analysis

The same model for green leaf producers and for barn owners was fitted under different discount rates (5%, 8%, 10%, 12%, 15%, and 18%). With higher discount rates net returns declined without changing the solution. This implies that regardless of the time preference, cultivation of carrot gives the highest net returns under the allowed level of soil loss. All the other sensitivity analyses were performed only for green leaf producers.

Further, in this analysis soil loss tolerance value was changed from 2.5 mt/ha/yr to 25 mt/ha/yr keeping other constraints unchanged. The results are presented in Table 3. Relaxing soil loss constraint from 2.5 to 20 mt/ha/year has increased the net returns marginally; Rs. 6779/- (5.4%). However with the relaxation of soil loss constraint the activity levels in the optimum solution changed considerably as shown in Table 3. Above a soil loss of 20 mt/ha/yr allows farmers to grow carrot without any soil conservation which may not be acceptable from the environmental management point of view. Here, again when soil loss restriction is relaxed, tobacco is not in the solution, suggesting that tobacco does not come to the solution, not only because of high soil loss but also due to the comparatively lower returns of the crop.

Table 3. Net returns and activity levels of the optimal solution under different soil loss values.

Soil loss mt/ha/yr	Net return Rs./ha	Activity levels ha
2.5	124861	C1 = 0.777 , C3 = 0.222
05	125999	C1 = 0.15 C2 = 0.840
10	128168	C1 = 0.477 C2 = 0.522
15	130338	C1 = 0.803 C2 = 0.196
20	131640	C1 = 1
25	131640	C1 = 1

Capital availability is one of the major constraints faced by the farmers living in this area (Gunatilake, 1990). In the initial model, Rs 35,000/- was given as initial capital. One could consider this as an unrealistic figure, given the income levels and other socio-economic conditions of the study area. Therefore, a sensitivity analysis was also performed for different levels of available capital. As one can expect with low levels of capital the net returns declined and the activity levels also changed. An important observation made, however, is that when the initial capital is as low as Rs 10,000/- tobacco without any conservation measures (T1) appeared in the solution. To be more realistic, the soil loss tolerance was also changed keeping capital at a low level (Rs. 10,000/-). The results are presented in Table 4. As indicated by the results, with the relaxation of soil loss constraint tobacco without conservation (T1) gradually increased and the net return showed a considerable decline. The model with a low level of capital and relaxed soil loss represents the real situation in the area and results explain that under these circumstances farmers tend to grow tobacco without soil conservation.

There has been a growing realization on the relationship between poverty and land degradation. Blaike (1986) describes the mutually reinforcing nature of poverty and soil erosion, while the report of the World Commission on Environment and Development (WCED 1987) recognizes poverty as one of the major factors that contributes to land degradation. Gunatilake (1990) shows that the soil erosion problem is severe among most exploited groups of tobacco farmers, sub-growers and unregistered growers.

Table 4. Net returns and activity levels of the optimum solution under low capital with different levels of soil loss tolerance values.

Soil loss mt/ha/yr	Net Return Rs./ha	Activity levels ha
10	40974	T1 = 0.10 CP2 = 0.50
15	36802	T1 = 0.17 CP2 = 0.42
20	32630	T1 = 0.26 CP2 = 0.35
30	24298	T1 = 0.41 CP2 = 0.19
40	15944	T1 = 0.57
50	15944	T1 = 0.57

The above results provide empirical evidence for this thesis, since lack of capital is an indication of poverty, together with other circumstance such as poor institutional support for alternative crops, force farmers to grow erosive crops and the process itself creates impoverishment. This is elaborated well in Figure 1 which illustrates that the increasing level of T1 (tobacco without soil conservation) reduces the net returns.

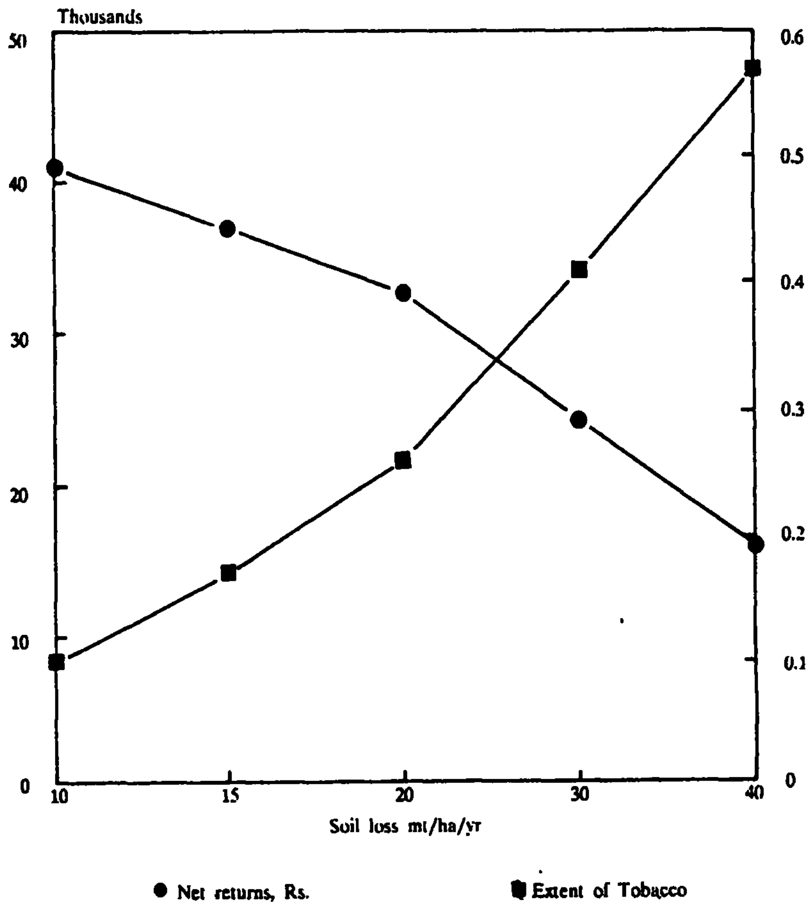

Figure 1. Impact of low capital and relaxed soil loss on net returns.

CONCLUSION

According to the results of this study, tobacco cultivation does not give the maximum returns when soil loss is restricted to soil loss tolerance level. Even if there is no soil loss restriction in the model tobacco does not appear in the optimal solution. Therefore, tobacco is not an acceptable crop in terms of net returns to the farmer and soil loss. Due to lack of soil loss data, only two vegetable crops were included in the study and among the crops studied, carrot gives the highest returns to the farmer. Among the studied soil erosion control practices, bench terrace is capable of reducing soil loss up to the soil loss tolerance value while giving maximum returns to the farmers.

Further, this study provides empirical evidence to support the theory of reinforcing nature of the poverty and land degradation. It is clear from the study that it is rational for farmers to grow tobacco without erosion control measures under low capital availability and resulting yield reduction impoverishes farmers further. Therefore, an external flow of capital, probably in the form of credit, is required to break this vicious cycle.

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