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Impact of Selected Macro-Economic Policies on Soil Erosion in Sri Lanka

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ABSTRACT. *Agriculture is a dominant economic sector in Sri Lanka. However, there is evidence that the growth of the agriculture sector has led to long term resource degradation, particularly soil erosion. Empirical evidence on the impact of economic policies on soil erosion in Sri Lanka is scanty. The few studies done in Sri Lanka have not incorporated the dynamics of policy impacts on soil erosion. The objective of this study was to quantify the causal linkages between selected economic policies on soil erosion.*

A semi-partial dynamic equilibrium model was used to simulate four supply functions for potato, bean, other vegetables and rice with an erosion function. Supply functions consist of quantity supplied as the dependent variable and own price, cross prices, fertilizer price as independent variables. A log-log functional form is specified for supply functions. In addition, soil depth is also included as an independent variable. The soil erosion function was specified in relation to quantities supplied. The model was simulated for 10 years using secondary data.

The results showed that there is a significant impact of economic policies on soil erosion. Further, the study quantified the impact of different policies on soil erosion compared to the base level of soil erosion. Tariff reduction on potato reduces soil erosion, which is consistent with the previous findings. For example, 10% reduction in potato price reduces soil erosion by 0.44%. The investment on soil conservation also reduces erosion by 8.99%. A 10% reduction in input prices reduces the soil erosion by 8.63% while 10% reduction in fertilizer price and investment on productivity improving research increase soil erosion by 8.63% and 8.48%, respectively. These quantitative results could be used in creating awareness among policy makers on the relative significance of economic policies on soil erosion, hence facilitating rational policy decision making to achieve sustainable development.

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INTRODUCTION

Agriculture is a dominant economic sector in Sri Lanka as in other developing countries and agricultural output has grown at an impressive rate (which is 2.6% during the period of 1991-95) over the years (Central Bank of Sri Lanka, 1996). Agriculture accounts for 18.4% of Sri Lankan GDP and 47.7% of the labour force (Central Bank of Sri Lanka, 1997).

It is believed that past growth in the agriculture sector in Sri Lanka has led to resource degradation, with adverse implications on sustainability of future agricultural growth. In 1989 the total extent of degraded land in Sri Lanka was about 10.8% of the total arable lands (Bandarathilake, 1989). Land and water degradation, particularly soil erosion is more prominent in the areas of steeply sloping lands of the central hilly regions. It has been found that the soil erosion rates in uplands can be as high as 100 tonnes ha^{-1} yr^{-1} (Bandarathilake, 1995). Soil erosion has direct on-site effect of reduced crop productivity due to reduced fertility and degraded soil structure. Further, it has off-site effects such as reduction in quality of water available for downstream and reduced irrigation and hydro-power generation capacity due to reservoir siltation (Bandara and Coxhead, 1995).

Population growth and slow labour absorption by the manufacturing sector and services industries has exerted pressure on land for agriculture, which leads to encroachment of forest lands and increased soil erosion (Jewell and Legg, 1994). On the other hand, most annual crops grown on sloping lands, including many widely grown food crops, tend to generate high rates of soil erosion (Stocking, 1992; Bandarathilake, 1995). In addition, market failures and policy failures leads to divergence between optimal private rate of soil erosion from social rates leading to non-adoption of soil conservation (Barbier, 1996).

Individual decision making is dependent on market prices and when market prices do not account for real resource values (*i.e.* market failure) resource use level would not be socially optimal. Market failures could be due to prevalence of natural monopolies, non-attenuated property rights, externalities, public goods and divergence of private and social discount rates (Barbier, 1996).

Economic policies could take the two main forms of fiscal and monetary policy. Fiscal policies would include direct government investments on different economic sectors, setting of taxes, subsidies, tariff rates that influence private investment/production and consumption behavior. Monetary policy refers to the government influences on interest rates and exchange rates through interventions on demand and supply of money, both local and foreign exchange. In addition the government could support the perfect functioning of markets through legislative/institutional policies. For example, the government could support institutions enforcing non-attenuated property rights.

In order to facilitate the implementation of policies, to correct market failures and to remove policy failures, it is necessary that policy makers are made aware of linkages between macro-economic policies and soil erosion. Among the literature on linkages between economic policies and environment the World Bank Report shared by Munasinghe and Cruz (1995) has made a significant contribution. They have reviewed case studies in the countries like China, Costa Rica, Ghana, Indonesia, Zimbabwe *etc.* and highlight the linkages between economywide policies and the environment. The impact on the environment can be either beneficial or harmful. Devaluation of currency and the subsequent increase in profitability of eco-tourism based on environmentally friendly wildlife industry in Zimbabwe is an example of beneficial impacts. The example of harmful impacts are: (i) in Thailand, the absence of clear delineation of property rights induced farmers to over-exploit fragile lands while industrial growth accompanied by adequate regulatory instruments was associated with major environmental damage and (ii) in Morocco, trade liberalization promoted economic expansion at the cost of increased water use.

There are several applications of general equilibrium analysis in the Sri Lankan context to quantitatively determine the impact of macroeconomic policies on environment (Bandara and Coxhead, 1995; Chisholm *et al.*, 1997). These studies necessitate the requirement of general equilibrium analysis and showed that trade liberalization will most likely reduce soil erosion.

The above general equilibrium studies have made a major contribution by integrating the different sectors in policy analysis. However, they have not included the dynamics of the impact of a policy on soil erosion over the years. Thus, the purpose of this study is to incorporate the dynamics of policy impacts on soil erosion.

The general objective of the study is to quantify the linkages between selected macroeconomic policies and soil erosion in the Nuwara Eliya district of Sri Lanka. Macroeconomic policies considered include (i) trade policies (trade liberalization of potato market), (ii) price policies (subsidy on fertilizer), (iii) monetary policies (simultaneous decrease in input and output prices),

(iv) research policies, and (v) environmental policy (conservation of land). The specific objective of the study is to examine the impact of potato trade liberalization, fertilizer subsidy, simultaneous decrease in all prices, research, and conservation on the supply level of crops and soil erosion over a period of 10 years in the Nuwara Eliya district of Sri Lanka.

METHODOLOGY

Crops grown in the study area are considered as potato, rice, bean and other vegetables where other vegetables consist of cabbage, khol rabi, carrot, leeks, beetroot, radish, tomato, capsicum, ash pumpkin, red pumpkin, cucumber, bandakka, binjals, bitter gourd, snake gourd, ash plantain and onion. The following dynamic semi-partial equilibrium model is conceptualized assuming that the crops grown in the area are as above.

Conceptual framework

Suppose the producers supply function[1] for potato, bean, paddy or vegetables is shown as Equation 1.

$$S_{it} = f\,(PP_t, PB_t, PR_t, PV_t, PF_t, D_t) \qquad (1)$$

Where, S_{it} = Supply of potato, bean, rice or vegetable at time t
Pp_t = Price of potato at time t
Pb_t = Price of bean at time t
Pr_t = Price of rice at time t
Pv_t = Price of other vegetables at time t
Pf_t = Price of fertilizer at time t
D_t = Soil depth at time t

The erosion level at year t (ERO_t) due to the production of crops at year t is given as indicated in Equation 2.

$$ERO_t = f(SP_t, SB_t, SR_t, SV_t) \qquad (2)$$

1 Supply of each crop was formulated as a function of its own price, cross prices, fertilizer price and soil depth.

Thus, the total erosion of the current year is considered as the total of erosion due to each crop. Erosion then can be converted into depth through the Equation 3;

$$CD_t = f(ERO_{t-1}) \qquad (3)$$

where CD_t is the change in soil depth at the year t due to the soil erosion at year t-1. The depth at year t (D_t) is the initial soil depth (D_{t-1}) adjusted by change in soil depth due to soil erosion at year t-1 (Equation 4).

$$D_t = D_{t-1} - CD_t \qquad (4)$$

Equations (1) to (4) form a system of equations which can be simultaneously solved for the quantities of supply of potato, bean, vegetable and paddy. In order to simulate the model, (i) functional forms must be imposed, (ii) parameter estimates are required, and (iii) base values for quantities and prices are required. The following section discusses each of the above issues in detail.

Functional forms

A log-log functional form was used for supply functions. The coefficients of log-log function are the respective elasticity values. A linear functional from was used in all other equations.

Policy instruments

Model was first calibrated for 1997 prices and quantities and then was used to evaluate the impact of the following policies.

Scenario 1: Potato trade liberalization

1.1 : 50% tariff reduction induced by 10% reduction in potato price[1].

1 Current rate of tariff is 35% and the domestic price of potato is 30.50. The tariff rates would be eliminated under SAFTA by the year 2001.

1.2 : 75% tariff reduction induced by 20% reduction in potato price.

Scenario 2: Fertilizer subsidy

2.1 : Induced by 10% reduction in fertilizer price.
2.2 : Induced by 20% reduction in fertilizer price.

Scenario 3: Soil conservation

It is assumed that conservation reduces soil erosion. Thus, the policy is imposed by reducing erosion rate by 10%.

Scenario 4: Input prices were reduced by 10%.

Scenario 5: Investment on cost of production reducing research.

It is assumed that investment on cost of production reducing research shifts the supply function to the right and thereby increases the intercept at the quantity axis. Thus the policy is imposed by adding 0.1 to the existing intercept of the supply functions which is equivalent to a 10% reduction in marginal cost.

Parameter estimates

Elasticities of supply with respect to own prices were obtained from the previous estimates. The values used are given in Table 1. The cross price elasticities were set so that the total of the cross price elasticities and the elasticities with respect to fertilizer are equal to zero. This satisfies the condition of homogeneity of degree zero of the supply function. The elasticity of supply with respect to soil depth was assumed as 0.13 which is reported by Ananda (1997) for maize and beans.

The coefficients in the erosion equation and in the depth equation were obtained as follows. The coefficient in the erosion equation indicates the change in soil loss due to a unit change in supply. The available estimates on the soil loss values for different crops are expressed in MT ha^{-1} $year^{-1}$. These values were divided by the per ha yield of each crop to obtain the required value in MT kg^{-1} $year^{-1}$. Table 2 presents the values used and coefficients obtained.

Table 1. Elasticity estimates available from previous studies.

	Potato	Beans	Paddy	Vegetables	Fertilizer
Potato	0.28*				
Beans		0.341**			-0.12***
Paddy			0.14***		-0.04***
Vegetables				0.80***	-0.65***

* Marasinghe (1997) ** Gunawardena (1980) *** Shumway *et al.* (1987)

Table 2. Soil loss per kg of supply.

Item	Potato	Bean	Paddy	Vegetable
Soil loss[1] tonnes ha^{-1}	100	70	5	100
Yield kg ha^{-1}	10118	3882	2558	12214[2]
Soil loss tonnes kg^{-1}	0.01	0.018	0.002	0.008

The coefficient in the depth equation indicates the change in soil depth due to a unit change in erosion. The soil depth and erosion were linked by the bulk density of soil, which was 13.

1 Stocking (1992), Bandarathilake (1995).

2 Weighted average of the yield of each vegetable under consideration was taken as the average yield.

Base values

Base values are required in order to calibrate the model for the base case. Data on quantities and price levels are required for 2 years and the model will forecast the supply levels for the future years for the given prices. Data used for the first two years are presented in Table 3 and the prices for the future years were assumed to be same as 1996 prices.

Table 3. Base values used.

	Potato	Beans	Paddy	Vegetables	Fertilizer
Supply (MT) (1995)	51713	7146	20000	67190	
Supply (MT) (1996)	27004	7414	17000	105284[1]	
Price (Rs kg^{-1}) (1996)	30.50	15.28	10.46	12.54	9.00

Source: Department of Census and Statistics (1997).

RESULTS AND DISCUSSION

The third row of Table 4 represents the base values obtained from the simulation of the model for 10 years with the base values given in the previous chapter (Tables 1 and 2). The impacts of different policies were evaluated based on these base simulation results.

Supply levels

Reduction of potato price decreases the supply of potato while increasing the quantities of bean, vegetables and paddy (Table 4). This result

1 Weighted average of supply of each vegetable under consideration was taken as the average supply.

is expected, since bean, vegetables and paddy were modeled as substitute crops in the model. A decrease in potato price makes producers move away from potato towards the other crops.

As expected, fertilizer subsidy and soil conservation increased the supply of all four crops. Decrease in fertilizer price increases supply levels since the elasticity of supply with respect to fertilizer price is negative for all crops. Farmers are assumed to be profit maximizers and hence when the price is reduced farmers use more fertilizers to increase the supply. A 10% reduction in input prices reduces the quantity supplied in all crops. On the other hand investment on research increases the supply of all four crops. As it has been assumed investment on research increases the supply due to increased productivity.

Land extent

Impact of different policies on total land extent (land extent under cultivation of all crops) is represented by the 6^{th} column of the Table 4. Trade liberalization on potato increases the total land extent. This is due to the fact that increased supply of other crops not only utilizes the land released by potato but some excess lands have been used by the other crops. Similar results were observed when soil conservation policy is imposed. As expected fertilizer subsidy and investment on cost of production reducing research increases the total land extent and reduction in prices of all inputs reduces the total land extent under cultivation. Fertilizer subsidy makes farmers to use more fertilizer and thereby increase the supply. Increased supply is based on increase extent of land for cultivation.

In this study, the land area under cultivation is not restricted. In other words, it is assumed that farmers encroach state lands as a response to policy changes. More than 80% of the land in Sri Lanka is under state ownership. The state land ownership survey of 1979 reported that 10% of government land was encroached (Minifie, 1997). However, the current rate of encroachment needs to be established through further empirical studies. Thus, any policy which changes the supply will change the area of land under cultivation.

Table 4. Impact of different policy instruments on supply, erosion and land extent, evaluated for the period.

Policy instrument	Supply (MT)				Land Extent (ha)	Erosion (MT)
	Potato	Beans	Vegetables	Paddy		
Base	268549	73730	1047030	169062	320265	12827
10% reduction in potato price	246316	74464	1064040	171009	322410	12771
20% reduction in potato price	229172	75072	1078280	172627	324347	12735
10% reduction in fertilizer price	277644	76686	1179570	168446	348196	13934
20% reduction in fertilizer price	285422	79229	1302590	167913	374028	14951
Soil conservation	271863	74640	1059950	171147	324226	11674
10% reduction in all prices	261467	73070	1029390	169850	316172	12625
Investment on cost of production reducing research	293701	80636	114509	184895	350260	13915

Erosion level

Trade liberalization of potato decreases the supply of potato and increases the supply of other crops. Although this resulted in an increased total land extent under cultivation, soil erosion decreased since potato is a more erosive crop (Table 4). Reduction of soil degradation due to trade liberalization also has been observed by Bandara and Coxhead (1997). Fertilizer subsidy and investment on cost of production reducing research, increase soil erosion while soil conservation and reduction in input prices decrease soil erosion. As it has been explained, reduction in fertilizer price increase the supply of crops and thereby increase the soil erosion. On the other hand, farmers tend to use more fertilizers rather than conserving the soil when fertilizer is cheap. This could also lead to increase soil erosion.

The percentage change in soil erosion due to different policy instruments are given in Table 5. Among different price policy instruments fertilizer subsidy has the biggest impact on soil erosion. For example 10% reduction in potato price could only reduce erosion by just 0.44% whereas 10% reduction in fertilizer price (fertilizer subsidy) increases erosion by

8.63%. Soil conservation and research policies also have a great impact on environment.

Table 5. Percentage change of soil erosion due to different policy instruments.

Policy Instrument	Percentage Change
10% reduction in potato price	-0.44
20% reduction in potato price	-0.72
10% reduction in fertilizer price	8.63
20% reduction in fertilizer price	16.56
Soil conservation	-8.99
10% reduction in all prices	-1.58
Investment on cost of production reducing research	8.48

CONCLUSIONS

Simulation results of the study showed that the macroeconomic policies considered have a significant impact on environment, specifically on erosion level. The magnitude of the impact differs with different policy instruments, *i.e.*, type of policy and the degree of policy change. The results show that fertilizer subsidy and investment on cost of production reducing research have the greatest detrimental impact on environment. As expected, conservation has the greatest favorable impact on environment.

The results are sensitive on the elasticity values used in the supply functions and erosion function. Magnitude of the cross price elasticities determines the magnitude of the change in supply levels of other crops when potato price is changed. The amount of change in supply levels of all crops then determines the level of erosion. When the above elasticities were used, trade liberalization of potato decreases soil erosion since potato is more erosive than other crops. This result is consistent with the findings of Bandara and Coxhead (1997). However, the results of this study are only suggestive rather than conclusive given the assumptions and validity of the secondary data. The results highlight only the environmental impacts of macro-economic policies. Choice of policy should be based on trade-off between negative environmental impacts and economic gains. However, the results of the model simulation can be useful for providing guidelines for policy making to achieve sustainable development.

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