ELSEVIER

Analysis

The cost of soil erosion in Nicaragua

Knut H. Alfsen [a,*], Mario A. De Franco [b], Solveig Glomsrød [c], Torgeir Johnsen [d,1]

[a] *Statistics Norway, PO Box 8131 Dep., N-0033 Oslo, Norway*
[b] *INCAE—Instituto Centroamericano de Administración de Empresas, Managua, Nicaragua*
[c] *Statistics Norway, P.O. Box 8131 Dep., N-0033 Oslo, Norway*
[d] *Statistics Norway, P.O. Box 8008 Dep., N-0030 Oslo, Norway*

Abstract

The cost of soil erosion is not so much dependent on the physical amount of soil lost as determined by the *economic effects* of these losses. Soil erosion has both onsite and offsite effects. Loss of soil productivity is the main onsite effect, while enhanced productivity of downstream land, sedimentation and eutrophication of waterways and reservoirs are common offsite effects. In this paper we consider only the onsite effects of erosion. The loss of agricultural productivity is, however, studied within a broader economic framework than usual. By incorporating the direct economic effects of soil loss into a general equilibrium model, it is possible to shed light on some of the many interlinkages between agricultural activity and other parts of the economy which are important for determining the social cost of soil erosion. Based on model simulations, we find that soil erosion represents a considerable drag on the Nicaraguan economy, but that the burden of soil erosion depends on conditions and policies in non-agricultural markets such as the labour market. Furthermore, the sharing of the burden is not always to the disadvantage of the peasants. While uncertainties in data and modelling prevent us from drawing strong conclusions, the present study underlines the importance of considering the overall economic environment when policy proposals for mitigating excessive soil erosion is formulated.

Keywords: Soil erosion; Environmental valuation; Economic growth; Nicaragua

1. Introduction

Soil loss is proceeding at a rapid rate in Nicaragua as the present situation is unfavourable for soil conservation efforts. Conflicts over ownership of land

---

* Corresponding author. Tel.: (+47-22) 86 49 45; fax: (+47-22) 11 12 38; e-mail: kha@ssb.no.
[1] Present address: Ministry of Finance, PO Box 8008 Dep., N-0030 Oslo, Norway.

together with a perceived credit shortage make investments in soil-conserving technologies unattractive to many peasants. Continued soil loss might undermine future income generation and represents an important barrier to economic development.

We aspire to provide some insight into how soil erosion affects the Nicaraguan economy and some of its main actors. The major onsite effect of soil erosion is a decline in soil productivity. The macroeconomic effects of reduced agricultural productivity are studied by means of a general equilibrium model

for the Nicaraguan economy. Production in the agricultural sectors is reduced directly due to productivity decline and indirectly through interactions with the rest of the economy. Production in non-agricultural sectors is reduced because rising food prices and rising wages increase the general domestic cost level. These changes affect foreign trade, domestic production and income distribution. Also, the level of rural and urban employment responds, giving rise to changes in the urban–rural migration pattern.

At the outset, the statistical basis for making such an integrated economy–environment analysis is weak. For instance, the productivity effect of soil erosion has been assessed by a local soil scientist (Marín Castillo) and the quality of the economic statistics can be questioned. Nevertheless, the early creation of a framework for an integrated model based analysis provides several methodological and political advantages. First, a model framework might discipline the collection of the environmental statistics, focusing from the beginning on information that is relevant for policy decisions. Second, the results of the analyses might initiate a dialogue between the parts of the administration dealing with economic affairs and with the environment, respectively. Normally, this dialogue is difficult to establish before the link between the two policy areas is quantified. Economic crises like the one in Nicaragua today make a dialogue on rather long-term environmental problems difficult to sustain. However, an integrated analysis might contribute by illustrating that environmental protection can increase traditionally measured economic growth and hence the scope for development.

The purpose of the study is somewhat limited compared to a complete soil erosion cost study. Due to lack of data on soil conservation cost, our first step is to see how economic forecasts for Nicaragua will overestimate future growth if no soil conservation is practised and no adjustments are made for declining agricultural productivity in the years to come. This baseline scenario is then compared to an alternative scenario where the productivity losses due to erosion are incorporated. In this manner we obtain estimates of the effects of soil erosion on prices and economic growth, together with some indications of its effect on the distribution of income and migration.

2. Soil erosion: physical characteristics

Soil erosion can be defined as detachment and removal of soil by wind and moving water. In this process, and in particular under heavy rainfall, the structure of the soil deteriorates. *Gully erosion* causes deep trenches in localised areas, usually removing much of the soil profile. *Sheet erosion* affects only the upper part of the soil profile, but covers larger areas. Gully erosion has the character of a localised catastrophe, while sheet erosion has a more gradual effect over a wider area. In this paper we will only consider sheet erosion. *Onsite effects* refer to effects at the site where soil is removed. *Offsite effects* involve the impact of soil depositions such as pollution, siltation and clogging of waterways, and increased flooding of lower land. This work is limited to analysis of the onsite effects of water erosion.

2.1. Natural conditions determining the rate of erosion

Water erosion occurs when rainfall exceeds the soil's capacity to let water infiltrate the ground, forcing the water to run off on the surface carrying away soil. Surface flooding is therefore crucial for the magnitude of soil erosion. Under continuous vegetation the soil's capacity to absorb water is high. The high content of organic matter and roots creates a structure of macropores for the water to infiltrate. In addition, litter, roots and stems impede the speed of water, facilitating infiltration. Vegetation covering the soil reduces the kinetic energy of the raindrops before hitting the soil, thereby protecting the soil structure. Forest is the most efficient soil cover. To clear forest usually initiates rapid erosion. In addition to rainfall, other natural factors affect the erosion rate. Steep terrain accelerates the surface flooding, and soil consisting of fine particles (rich in organic matter) is more easily eroded than coarser soil. Thus, for a particular vegetation cover, the erosion rates vary according to climate, topography and type of soil.

Soil erosion is a process that is inherent in nature, but the rate of erosion can be drastically increased by intensified agricultural activity. Under undisturbed vegetation there is normally a balance between the soil erosion and the soil formation processes. Culti-

vation of the land usually interrupts this balance, because the vegetation cover is reduced.

2.2. Soil loss and soil productivity

The onsite economic impact of soil loss is due to yield reductions. Several factors can make soil productivity fall. In the following, we briefly mention some dominant hypotheses, based on Lal (1987).

The soil provides the growth medium for the plants. As soil and nutrients are removed, the *rooting depth* for the plants is reduced. The consequence of lower rooting depth is more severe on shallow soils, which are predominant on sloping land, than on deep soils.

Drought stress is particularly serious in eroded uplands. *Water-holding capacity* is reduced by the selective depletion of organic matter and fine particulated clay contents. Furthermore, erosion increases the frequency, duration and intensity of drought.

When the topsoil is lost, the subsoil is exposed. This soil normally has a poorer structure and is more compact. *Water infiltration capacity is reduced*, which in turn may lead to increased surface runoff and accelerated erosion.

The rate of soil loss, characteristics of the soil profile, climate and crop grown decide how much soil erosion lowers the productivity of land. There are different views as to whether the cause of productivity loss is primarily due to the reduction in plant-available water, to reduced or unstable supply of nutrients due to a decreased water storage capacity, or to nutrient loss as such.

It is important to note that several phenomena prevalent in the tropics make soil degradation a more serious concern there than in temperate regions. The typical rainfall in tropical regions is more concentrated in time and heavier than in temperate regions. Also, the tropical soils are usually more fragile, containing less organic matter. Seasonal abundance of water easily generates floods, and water storage capacity is a limiting factor in dry periods.

3. The cost of soil erosion

The erosion-induced loss of soil productivity may represent an economic cost to the individual farmer

and to the society. Several methods for calculating the economic cost to society of a given loss of soil have been proposed in the literature (see, for instance, World Resources Institute and Tropical Science Center (1991), Magrath and Arens (1989), Fox and Dickson (1988) and Devarajan and Weiner (1991)). Some cost estimates are very narrow and rely on, for example, only the replacement cost of nutrients lost. Others are based on Hicks' concept of income (Hicks, 1946). Not all loss of soil is necessarily considered as an economic cost under this approach. If technological development takes place in the economy, some degradation of soil can be allowed without undermining the future consumption level. In the so-called wealth approach, soil is considered as a form of wealth providing an income stream. The cost of soil erosion is then calculated as the present value of future income loss due to soil degradation. Ideally, the cost should be evaluated in shadow prices: that is, the prices that govern in optimum where all resources are used efficiently.

The approach employed in this study is somewhat limited compared to a complete soil erosion cost study. Our first step is to see how economic forecasts for Nicaragua will overestimate future growth if no soil conservation is practised and no adjustments are made for declining agricultural productivity in the years to come. This baseline scenario is then compared to an alternative scenario where the productivity losses due to erosion are incorporated. In this manner we obtain estimates of the effects of soil erosion on prices and economic growth, together with some indications of its effect on the distribution of income and migration.

4. Soil erosion: Why is it an economic problem?

If there is excessive soil erosion, why do the affected farmers not engage more heavily in soil conservation? After all, soil erosion is not like many other environmental problems which more often are linked to open access situations. In the case of land, private ownership can at least in principle be defined, and thus the cost of erosion internalized.

There are several reasons that may explain this situation. Below we mention some barriers to long-term investments in soil conservation which are likely

to affect the Nicaraguan peasants—in particular the poor—in their soil management practice.

Soil degradation is a slow process, implying relatively small annual changes which are hard to detect when crop yields in any case vary considerably due to management, plagues, precipitation and other factors. For instance, increasing drought problems may be blamed on less rainfall instead of increasing loss of water through surface runoff and associated reduction of water storage capacity.

Technological improvements may hide the impact of soil degradation. In Nicaragua, fertiliser and pesticides were strongly subsidised during the 1980s. The increase of inputs may have boosted yields and possibly masked the impact of erosion.

Even if farmers were aware of the degradation and knew how to prevent it, it might be regarded as too costly for the farmer to change technology. The costs are immediate, while the benefits will be spread out over a long time horizon. The discount rate may in particular be high for poor farmers. In their case, a delay in consumption to invest in soil conservation means less food, at times even starvation.

Even farmers who are motivated and able to invest in soil conservation may hesitate due to insecure property conditions. Several factors have made property conditions insecure in Nicaragua. In the recent past, peasants were forced to leave land which was subsequently converted to large-scale export production. Also, during the Contras war hundreds of thousands of people fled from the battle areas. Today, the ownership of land is in many places insecure due to unsettled political struggle over the rights to former confiscated land and to some extent also the land distributed to the 120 000 families in the land reform during 1985–1989.

An additional reason why property rights may be seen as insecure is that the present economic policy has limited the amount of credit given to small peasants usually short of working capital, reducing their potential to produce and generate income even when an income potential is present. [2] Thus, for

many peasants a likely outcome of the current credit shortage is to abandon the land.

The limitation of credit in itself makes it harder to switch to less erosive crops even when this is more profitable for the farmer. Annual crops (staple food) are more erosive than perennial crops (coffee, fruit trees) under prevailing cultivation practice. However, perennial crops will not produce yields until after several years and credit would make a shift more feasible. Unfortunately, the least credit-worthy peasants are in fact the small peasants cultivating the most erosive crops in the least appropriate topographic areas.

5. Soil erosion in Nicaragua

5.1. General description of the country and the agricultural activity

Nicaragua is divided into two distinct parts facing the Pacific Ocean and the Caribbean Sea, respectively. The great majority of the population and economic activity is located in the Pacific part, divided administratively into six regions. The three special zones making up the Caribbean coast contain most of the land area. Except for some production of basic grains, the value of agricultural production in this part of the country is insignificant. The degradation of the soils is connected to leakage of nutrients from soils of low inherent fertility (vertisols) rather than to erosion. We have therefore chosen not to include the Caribbean coast in this work.

Located 10–15 degrees north of the equator, the climate in Nicaragua is tropical to sub-tropical with even temperatures throughout the year. Within the

---

[2] Even under the Sandinistas when small peasants had access to credit, this was usually in the form of short-term credit for food production only, and thus unavailable for investment in soil conservation.

Table 1
Definition of erosion classes

Erosion class	Fraction of horizon lost	Soil loss depth
Light	0–25% of horizon A	0–10 cm
Moderate	25–50% of horizon A	10–20 cm
Strong	50–75% of horizon A	20–30 cm
Very strong	75–100% of horizon A	30–40 cm
Severe	0–50% of horizon B	40–65 cm
Extreme	50–100% of horizon B	65–90 cm

Source: Marín Castillo (1979).

Table 2
Average annual erosion 1981–1990 by crop and region (tonnes/hectare)

	Region I	Region II	Region III	Region IV	Region V	Region VI
Beans	110	110	135	92	123	125
Maize	104	102	122	97	153	125
Sorghum	106	85	122	85	146	107
Rice	43	43	28	40	20	40
Sesame	..	148	140	130	..	..
Coffee	53	59	113	73	114	107
Cotton	..	106	147	132	..	..
Sugar	96	36	36	40	..	97
Tobacco	65	60	108	83	..	50
Vegetables	55	..	..	..	..	71
Pasture	148	83	104	109	115	175

Source: Marín Castillo, personal communication, 1992.

Pacific regions, precipitation ranges from a little below 1000 up to 2000 mm per year, with a marked dry period from around December to May. The year is divided into three growth periods: the "primera" from May to August, the "postrera" from September to December, and the "apante" from January to April. Because of water shortage, the "apante" is normally a rest period.

With respect to economic and technical development as well as to agroecologic characteristics, it is natural to separate the Pacific area into two parts: the Pacific coast (comprising the administrative regions II, III, and IV) and the Central region (comprising regions I, V, and VI). Except for coffee and beef, all the export agriculture (cotton, sugar, sesame, and banana) is found along the Pacific coast. The Pacific coast is to a large extent covered by young, fertile volcanic soils generally very susceptible to erosion. The most technically advanced agriculture has developed with the expansion of cotton production from the 1950s and on to the 1970s on the flat plains of León and Chinandega in region II. In region III, the fertile soils are located in somewhat more rugged and elevated terrain, making coffee the most important product. Region IV is the agriculturally most diverse region.

In the Central region, agricultural activity is dominated by the production of coffee and basic grains. In region V, however, little coffee is grown, but it is among the largest of the six Pacific regions in livestock production. Except for the lower parts of region V, and some valleys in regions I and VI, the Central region is largely mountainous, providing a cooler climate and a more rugged terrain than the rest of the country. The soils are generally fertile, but of older origin and less erodible than the soils along the Pacific coast.

5.2. Estimates of erosion and erosion-induced decline in soil productivity

Below we describe the procedure applied and the data sources used in estimating the annual soil erosion and the rates of erosion-induced productivity losses in the agricultural sectors.

The primary data source for the erosion estimates is an erosion map of Nicaragua in the scale of 1:522 000 published by the Government of Nicaragua (Marín Castillo, 1991). Here, the cultivated land is classified according to six erosion levels: Light, Moderate, Strong, Very strong, Severe, and Extreme. The erosion classes are defined by how large a fraction of the original soil profile is lost (see Table 1) (Marín Castillo, 1979). Based on an average depth of the A [3] horizon of 40 cm and the B horizon of 50 cm, the soil loss depth in centimetres is also shown.

---

[3] The soil profile is often divided into three horizons: A, B, and C. The A horizon is that part of the profile directly affected by agricultural activity, plant roots, etc. The B horizon is below the root depth, but still influenced by leakages of water and nutrients through the A horizon. The C horizon at the bottom is usually unaffected by agricultural activity.

Table 3
Erosion-induced yield decline by region, crop and erosion class: percent productivity compared to uneroded soil

	Light	Moderate	Strong	Very strong	Severe	Extreme
Maize regions I, IV, VI, beans	100	80	56	34	17	7
Coffee regions II, IV, V, VI	100	85	68	51	36	23
Coffee regions I, III	100	90	77	61	46	32
Pasture	100	100	70	39	15	6
All other	100	85	68	48	29	14

Source: Marín Castillo, personal communication, 1992.

The state and range of erosion by crop and region was assessed based on information from the erosion map and a land use map (INETER, 1983) supplemented with various soil studies (Marín Castillo, 1988, Marín Castillo, 1990, Marín Castillo, 1992). In this manner it was possible to estimate accumulated soil loss in tonnes/hectare[4] in 1970, 1980, and 1990 by region and crop. In Table 2 this is converted to average annual soil loss measured in tonnes per hectare by crop and region.

Next, a relation between erosion and erosion induced productivity loss was assessed. In principle, the assessment was subjectively carried out by local expertise (Marín Castillo) after having observed yield development by crop and region over the last 25 years. Accumulated soil is only one among several factors considered to affect soil productivity. Total yield decline by crop, region, and erosion class in 1990 compared to uneroded soil was assessed as shown in Table 3.

Hence, the relation between erosion class and erosion-induced productivity loss displayed in Table 3 is based on a qualified and partly subjective assessment. We do not know of Nicaraguan investigations on the effects of erosion on yields. It should also be kept in mind that yield levels are influenced by a number of interwoven factors, and it is particularly difficult to isolate the effects of erosion.

The average annual productivity loss by crop and region between 1980 and 1990 shown in Table 4 is based on the erosion status for those years and the yield decline reported in the previous table[5].

5.3. A computable general equilibrium (CGE) model for Nicaragua

When performing an exercise of estimating foregone earnings due to soil erosion, one should be aware that observed prices do *not* in general reflect the social cost of resources in the presence of market failures. Market failures related to allocation of credit and property are closely associated with the soil erosion problem itself. The Nicaraguan economy, like most economies, has plenty of other distortions as well. In this case estimated loss due to soil erosion based on market prices will generally deviate from the true social cost. Aware of this shortcoming, however, we use observed prices in the study of soil erosion in Nicaragua, as is done in cost estimates referred to previously.

The model used falls into the neo-classical tradition assuming that consumers maximize utility and producers maximize profit. The parameters are calibrated rather than estimated.

The model has 26 producing sectors each producing a single commodity. Of these sectors, 11 are classified as *agricultural* sectors, while the others are *urban* sectors. The commodities are produced by the input factors labour, capital and intermediates.

---

[4] The units were converted from % of profile to tonne/hectare by assuming that 1 cm soil corresponds to 1 tonne/hectare (a density factor of 1 tonne/m^3). In reality, the soil density varies, but using one single conversion factor is justified by the fact that, roughly speaking, the land with the deeper soils generally consist of soils lighter than 1 tonne/m^3 (light volcanic soils density 0.8–0.9 tonne/m^3), while in the areas containing shallower soils, the density is generally higher than 1 tonne/m^3.

---

[5] Maize is an important crop in Nicaragua. The productivity losses reported in Table 4 are comparable with results from Lyles (1975) concerning conditions in the corn belt of the USA. According to Lal (1987), these estimates are, however, low compared with the effects of soil erosion in the tropics.

Table 4
Average annual decline in soil productivity 1981–1990 by region and crop (percent)

	Region I	Region II	Region III	Region IV	Region V	Region VI
Beans	2.1	1.9	3.0	1.6	2.7	2.4
Maize	2.1	1.3	2.3	1.1	2.7	2.4
Sorghum	1.5	0.9	1.9	0.9	2.2	1.5
Rice	0.7	0.7	0.1	0.3	..	0.3
Sesame	..	2.2	2.4	2.1	..	..
Coffee	0.4	0.9	1.3	0.9	1.8	1.4
Cotton	..	1.3	1.9	1.8	..	..
Sugar	0.6	0.1	0.1	0.3	..	0.8
Tobacco	0.5	0.3	1.6	0.9	..	..
Vegetables	0.2	..	..	..	..	0.6
Pasture	3.0	0.6	1.2	1.9	1.5	3.0

Source: Marín Castillo, personal communication, 1992.

The intermediates are used in fixed proportions to the production levels, while there is substitution between labour and capital. The relative prices between labour and capital determine the mix of those input factors. Demand for labour is determined by equating the value of the marginal production of labour to the wage rate. High wages make producers substitute capital for labour so that demand for labour decreases in the real wage rate. The wage level is indexed to inflation (i.e., the consumer price index for workers), although we briefly also consider a case with wages fixed in nominal terms.

Investment in production capital is determined by the level of total savings. Foreign savings are assumed to be constant; so domestic savings are the essential variables for economic growth. Savings are proportional to income in four social classes. Since saving rates differ between classes, the income distribution influences the accumulation of production capital. The four social classes are Campesinos, Workers, Petty capitalists and Capitalists. Campesinos are agricultural smallholders, while big agricultural producers are counted as Capitalists. Workers are those formally employed as wage earners in either urban or rural sectors.

Income consists of profit, wages and transfers from abroad. Profit in a sector is determined as the price less indirect taxes and unit (wage and material) cost multiplied by total production. Total profit is distributed among the four social classes by fixed coefficients. Total income for workers is wage income plus transfers from abroad. Campesinos earn a constant share of the profit in the *agricultural* sectors while Petty capitalists receive a constant share of the profit in *urban* sectors plus transfers from abroad. Total income for Capitalists is a fraction of total profit in agricultural sectors plus a fraction of profits in the urban sectors and transfers from abroad. Savings equals total income less taxes and total expenditure.

Total labour supply is growing by a constant rate based on population growth forecasts. The labour market is not in equilibrium. For the labour market to be in equilibrium it would be necessary for wages to adjust according to the value of the marginal product of labour until the supply of labour equals demand.

The capital stock in period $t + 1$ is equal to the capital stock in period t less depreciation plus investment in period t. Total nominal investment equals the sum of investment by sector of origin. Allocation of investment by destination is determined by fixed coefficients. The sectoral pattern of investment by destination is translated into demand for investment goods by sector of origin.

Domestically produced goods compete with foreign goods both on the world market and at home. It is assumed that domestically produced commodities and imported goods of the same category are nonperfect substitutes (the Armington assumption). The relative prices determine the market shares. The higher the price of the domestically produced commodity relative to the price of the imported commodity, the higher is the import share. The lower the

price on exports relative to the world market price, the higher is the export.

World market prices (in dollars) are exogenous, and the nominal exchange rate is set by the government (held constant in this study). The prices of imported and exported goods are determined as the world market prices (in dollars) multiplied by the exchange rate and adjusted for tariffs.

Based on the economic development paths generated by the model, together with additional assumptions, it is possible to get some tentative information on the impact of erosion on urban-rural migration in Nicaragua. One possibility is to assume full employment in the rural sectors. On this assumption surplus labour will move to the urban areas, and it is possible to calculate the net migration under the different scenarios. An alternative is to assume that the relative relationship between income growth rates for peasants and urban workers decides the direction and size of migration of the labour force between urban and rural sectors. Later on we will investigate the outcome on both these assumptions. The Appendix gives a description of the equations in the model together with lists of sectors and variables [6].

5.4. Scenario analysis: Impact of soil erosion on economic growth

In this section we describe the results from simulations on the CGE model for Nicaragua. The focus is on estimated amounts of erosion (i.e., loss of soil in tonnes) and the macroeconomic effects of erosion due to productivity losses. The scenarios must not be interpreted as actual forecasts of the likely development of the Nicaraguan economy. Further work with the model is necessary in order to establish more realistic scenarios. However, the kind of scenario analysis performed here is useful in order to investigate the sensitivity of economic growth to erosion. We will therefore emphasize the *deviations* between scenarios rather than the actual levels of the economic variables.

The baseline scenario represents a standard fore-

casting approach, where the future decline in agricultural productivity due to erosion is disregarded. In this scenario, covering the years from 1991 to 2000, real GDP grows at an annual rate of 2.9 percent. Soil loss is assumed to be in constant proportions to area harvested by crop and region as reported in Table 2. Each crop is produced in a separate sector, while the regional distribution of each crop is assumed to be equal to the distribution in the base year (1991). Area harvested is in turn assumed to be proportional to production adjusted for changes in productivity. Over the period 1991–2000 Nicaragua will have lost a total of approximately 650 million tonnes of soil. This represents an average loss somewhat above 110 tonnes/ha. For comparison, we can mention that the World Resources Institute and Tropical Science Center (1991) calculate soil loss in Costa Rica over the period from 1970 to 1989 to be of the order of 2.2 thousand million tonnes, corresponding to an average loss of some 70 tonnes/ha.

Erosion reduces the productivity of the soil (i.e., yields are reduced for a given level of inputs). In this study we quantify the macroeconomic effects of erosion by letting the scale of erosion be reflected in the productivity of the agricultural sectors. The estimates of productivity reductions by crop and region are given above in Table 4. National data by crop are obtained by weighting regional productivity by each region's share of total production in the base year. The results are given in Table 5.

Sesame, maize and beans are the crops which incur the greatest productivity loss, while bananas,

---

Table 5
Erosion-induced productivity decline in 1991 (percent)

Sector	Annual loss of productivity
Coffee	1.26
Cotton	1.31
Bananas	0.00
Sesame	2.16
Sugar	0.13
Maize	2.41
Beans	2.52
Rice	0.33
Sorghum	1.35
Vegetables	0.13
Pasture	2.32

Source: Own calculations.

sugar and rice suffer minor productivity losses. Coffee, cotton and sorghum are in an intermediate position. Pasture incurs a productivity loss in line with sesame, maize and beans.

Although in general not perceived, the loss of productivity will, of course, reduce output in the agricultural sectors. This is acknowledged in our alternative scenario where the reduction in agricultural output reduces the demand for inputs from other sectors of the economy. Thus, production in other sectors is also reduced. All these effects are incorporated into the input–output core of the model. Table 6 shows the main macroeconomic effects of reduced productivity in agriculture due to erosion.

The table shows that GDP, imports, exports and consumption are reduced by from 4 to 7 percent compared to the baseline scenario in year 2000, while investment is reduced by 9 percent. The reduction in investment is somewhat larger than the reduction in the other variables and the reason for this is as follows.

Total investment equals total savings which consists of savings by households, government and foreign savings. Foreign savings are exogenous in the model while savings by households are determined as constant shares of the households' income. Government saving is determined by equating total government tax revenue to total government expenditure which is exogenous. With falling production, revenue from taxes declines and government saving is therefore squeezed. The reduction in household and government saving together implies a reduction in

investments of 9 percent. Table 7 shows the effects on output, labour and prices in the various sectors of the economy.

5.4.1. Production

An exogenous reduction in the productivity of the agricultural sectors reduces the production in these sectors both directly and indirectly. As Table 7 shows, it is the production of sesame, beans and maize that experience the largest reductions, because these sectors are most exposed to productivity losses from erosion. Among other agricultural sectors, production of bananas, sugar, rice and vegetables ("other agriculture") is far less exposed to erosion losses.

Reduced production in the agricultural sectors affects production in non − agricultural sectors, because fewer intermediate goods are needed in agriculture, but also because the domestic cost of production increases.

5.4.2. Demand for labour

Total demand for labour is reduced by almost 7 percent. There are, however, large variations between sectors with large increases in the use of labour in erosion-prone sectors like production of maize, beans and cattle. With some exceptions, the demand for labour decreases in other sectors. The demand for labour is determined by the activity level and the labour intensity (labour/output ratio) in production. Within our model, the labour intensity is in turn determined by the ratio of unit profit or "net" price and wage rate. In other words, the more

Table 6
Main macroeconomic variables, area harvested and loss of soil: average annual growth 1991–2000 and deviation from baseline scenario in the year 2000 (percent)

	Average annual growth in baseline scenario	Average annual growth in alternative scenario	Deviation from baseline scenario in year 2000
Real GDP	2.9	2.0	−7.3
Imports	2.0	1.6	−3.6
Exports	2.7	2.1	−4.6
Private consumption	2.3	1.6	−6.2
Investment	3.7	2.6	−9.1
Labour supply	4.3	4.3	0.0
Labour demand	2.3	1.5	−6.7
Area harvested	2.5	2.3	−1.9
Loss of soil	2.5	2.3	−2.0

Source: Own calculations.

Table 7
Sectoral output, labour, wages and producer prices: deviation from baseline in the year 2000 (percent)

Name	Output	Labour	Wages	Output prices
Coffee	−12.5	−4.5	4.2	7.4
Cotton	−16.3	−19.2	4.2	0.2
Bananas	−1.7	−4.8	4.1	0.0
Sesame	−23.1	−22.6	4.2	2.1
Sugar	−1.7	0.6	4.1	4.4
Maize	−20.5	13.5	4.1	25.9
Beans	−21.0	36.0	4.2	28.8
Rice	−3.2	15.9	4.2	2.4
Sorghum	−14.2	−37.8	4.1	−11.2
Other agriculture	−2.5	−1.6	4.1	0.0
Cattle	−18.7	59.8	4.2	25.3
Forestry	−1.2	1.3	4.3	2.4
Fishery	0.1	13.8	4.1	0.0
Mining	−1.8	−4.9	4.0	−0.1
Food and beverages	−1.7	−2.4	4.1	−0.1
Textiles	0.4	2.6	4.1	0.0
Chemicals	−0.9	−0.1	4.1	−0.2
Oil production	−2.1	−7.7	4.1	−1.5
Other industries	−0.8	0.8	4.1	−0.6
Electricity	−8.0	−8.9	4.2	0.8
Water services	−3.1	−5.2	4.2	1.5
Construction	−8.1	−13.8	4.1	−1.3
Other services	−5.2	−6.9	4.2	1.6
Transport and communication services	−4.3	−9.2	4.2	−0.9
Education and health	−1.0	−0.9	4.1	3.5
Trade	−5.9	−11.8	4.1	−2.0
Total	−6.0	−6.7	4.1[a]	1.7

Source: Own calculations. [a] Weighted with sector input of labour in the baseline scenario.

profitable the production relative to the wage rate, the more labour is employed. From Table 7 we see that erosion increases the wage rates rather uniformly by some 4 percent. This is because wages are indexed to the consumer price index for workers, which is considerably increased by the productivity losses from erosion. Declining production and rising wages consequently both tend to undermine employment opportunities. On the other hand, the price effects are ambiguous. For production of maize and beans and in livestock production the rise in net price (sales price less unit cost) is large enough to offset the negative impact of rising wages and falling production volume. Hence, more labour are employed in these sectors.

Demand for labour in production of sorghum is reduced by almost 40 percent. The large percentage reduction can, however, be explained by a very low initial use of labour. A small change in absolute numbers can therefore lead to large percentage changes.

Among the non-agricultural sectors, construction and trade experience the largest reductions in employment. Reduced investments hit the construction sectors particularly hard, while the price increase for agricultural products decreases the net price in the trade sector.

5.4.3. Wage formation

The changes in labour demand should be judged against the background of the wage formation relation of this model. The model assumes complete compensation of rising living costs for workers, independent of the unemployment level. In other words the real wage rate is *not* assumed to adjust downwards to assure full employment. Over a period of several years with high unemployment, it is doubtful whether such a wage formation rule could be sustained. It is more realistic that the real wage will fall and dampen the rise in unemployment. In that case, the negative impacts on economic growth will also be modified.

We have also simulated the impact of erosion in an economy with *fixed nominal wages*. This illustrates a situation where wage earners are offered no compensation for price increases, perhaps because of weak labour unions and a lack of political and

Table 8
Price effects of erosion: percent deviation from baseline in the year 2000

Price index	Change due to erosion in year 2000
Producer price index	1.7
Domestic price index	2.1
Consumer price index	4.9
Campesinos	5.8
Workers	4.7
Petty capitalists [a]	5.9
Capitalists	4.0

Source: Own calculations.
[a] The percentage change in prices differs from the change in this price index because wages are related to the price index lagged period.

strategic power among the workers. The effect of changing the wage formation rule is to dampen the erosion-induced changes in volumes and amplifying the price responses. The loss in real GDP is lowered from approximately 7 to 3 percent by the change in wage formation rule. The aggregated impact on labour demand is even larger: with fixed nominal wages erosion lowers the demand by less than half a percent (compared to the almost 7 percent reduction calculated on the basis of fixed *real* wages). Generally, we find that under a fixed nominal wage rule, price responses to erosion are larger and quantity responses lower than under the rule where wages are indexed. This illustrates an interesting linkage between environmental aspects of development and institutional arrangements.

5.4.4. Prices

The prices in the model are adjusted in order to equate supply with demand. A reduction in productivity will as a first-order effect reduce supply and thereby increase prices. Due to demand side-effects the demand curve will also shift downwards and the effect on prices is uncertain. Table 7 shows that some of the producer prices are reduced and that some are increased. The overall price level, measured by weighting price changes with sectoral products, is increased by 1.7 percent compared to the baseline scenario. The increase in prices is largest for maize, beans and cattle for the agricultural sectors and education and health among the non-agricultural sectors. The increase in the price of maize, beans and cattle more than offsets the reduction in production giving increased profit in these sectors. This indicates that the demand for basic food grains is rather inelastic. As a consequence a large part of the cost of erosion is passed on to other social classes than campesinos. [7] The price increase in education and

---

[7] This result illustrates a theoretical aspect concerning the depletion of natural resources in an open economy with trade noted by Asheim (1986). When natural resources are depleted, prices increase and improve the terms of trade and favour future consumers in the resource-exporting country. As a consequence, to maintain a constant level of consumption over time, it is not necessary to completely compensate the resource depletion by investment in other types of capital, as a part will be compensated by the rising terms of trade. If we think of campesinos as a separate trading economy, we note their improved terms of trade with the rest of the economy.

Table 9
Effect of erosion on consumption: percent deviation from baseline in the year 2000

Social class	Real private consumption
Campesinos	8.7
Workers	−8.7
Petty capitalists	−11.1
Capitalists	−6.9
Total	−6.1

Source: Own calculations.

health reflects that wages account for a high share of total costs in these sectors.

Table 8 shows the price effects of erosion in aggregate form. We note that consumer prices increase more than the producer price index. This is due to the heavy weight of food items in the consumer price indices, in particular for the poorer sections of the population. A further comment is that the change in the domestic price index reflects the impact of erosion on the *real* exchange rate, since both the world market prices and the nominal exchange rate are kept fixed in the model simulations.

5.4.5. Consumption, migration and the distribution of income

According to our simulations, campesinos as a land-owning class actually become better off by the erosion-induced productivity losses. This is because of their market power as food producers, which increases their profit due to the erosion. [8] This happens despite the (incomplete) competition from the world market. Worst hit by erosion are the Petty capitalists who see a decline in real consumption of 11 percent. In Table 9 the effect on consumption for the four social classes is shown.

The above information refers to consumption by classes. Any kind of welfare interpretation of these results must however take into account the number of people belonging to the different classes. This information is not directly available from the model. It is nevertheless possible to extract some information about the development in per capita income and consumption if we make some additional assump-

---

[8] Remember that campesinos get their income solely from the profit of the agricultural sectors.

tions. In Nicaragua approximately 71 percent of the population is classified as belonging to the urban part, while the remaining 29 percent belongs to the rural economy. The first question we face is how economic growth will affect this ratio. Two types of assumption seem possible. In the first case we assume that there is no unemployment in the rural sector. Thus, labour supply in the rural sector follows the demand for rural workers, and surplus labour is "exported" to the urban sector. On this assumption we find that net urban migration in the baseline scenario is of the order of 3.5 percent of urban labour supply on an annual basis, and that erosion-induced productivity losses *increases* this percentage rate to almost 4 percent.

A second possibility is to assume a relation between migration and expected wages in the two sectors. As an illustration we have assumed that the ratio of rural to urban labour supply is an increasing function of the growth in relative income of campesinos and workers. With this formulation we find a net urban migration rate of around 2.4 percent annually in the baseline scenario, and a marginally smaller value in the alternative (erosion) scenario. Thus, this assumption dampens urban migration and (barely) changes the sign of the impact of erosion on migration.

In either of these two cases we can get an indication of the impact of erosion on per capita income by calculating campesinos' income per unit rural labour supply and urban workers' income per unit urban labour supply. Comparing the changes in the relative sizes of these ratios in the two scenarios, we find an improvement due to erosion in the living standard of campesinos relative to urban workers of 14 percent in the case with no rural unemployment, and almost 20 percent in the case where migration is affected directly by the relative growth in income. In both cases we find that the price effect of erosion more than compensates for the decline in production in the agricultural sectors.

5.4.6. Unemployment and migration

In the baseline scenario, unemployment defined as the difference between total (exogenous) labour supply and labour demand, is increasing from 14 percent in the base year to 27 percent in the year 2000. By including the productivity losses due to

Table 10
Average annual growth in labour supply and demand, 1991 – 2000 (percent)

	Baseline scenario	Alternative scenario	Percent difference between scenarios
Total labour supply	4.3	4.3	0
Urban	4.8	4.9	1.1
Rural (equal to demand)	2.7	2.4	− 3.2
Total labour demand	2.3	1.5	− 6.7
Urban	2.1	1.0	− 8.6
Rural (equal to supply)	2.7	2.4	− 3.2

Source: Own calculations.

erosion, this latter unemployment rate increases to 32 percent.

Demand for labour, as calculated by the model, can be classified according to area by designating the individual sectors as either urban or rural. Following the classification shown in the sector list in the Appendix, we find that demand for urban workers grows at a rate of 2.1 percent in the baseline scenario, while demand for rural labour grows at 2.7 percent annually on average. Taking erosion costs into account reduces the demand for both rural and urban labour—rural relatively more than urban labour. Growth rates in this alternative are 1.0 and 2.4 percent on average for urban and rural labour, respectively.

In poor countries, everybody living in rural areas must work to survive. Thus, it may be a reasonable assumption to set labour supply equal to demand for labour here. Supply of urban workers can then be residually determined. Growth rates are reported in Table 10.

Table 11 reports on the corresponding unemployment levels.

Table 11
Unemployment in the year 2000 (percent)

	Baseline scenario	Alternative scenario	Percent difference between scenarios
Total unemployment	27	32	5
Urban areas	37	43	6
Rural areas	0	0	0

Source: Own calculations.

Table 12
Effect of erosion on imports and exports: percent deviation from baseline scenario in the year 2000

Sector	Import	Export	Net import
Coffee		-45.8	45.8
Cotton		-46.1	46.1
Bananas		-2.8	2.8
Sesame	0.0	-10.6	10.6
Sugar			—
Maize	2.1		2.1
Beans	0.9		0.9
Rice	-0.3		-0.3
Sorghum	-0.1		-0.1
Other agriculture	-0.4	-4.7	4.3
Cattle	0.2		0.2
Forestry	0.0	-0.0	0.0
Fishery		0.1	-0.1
Mining	-1.1	-1.4	0.3
Food and beverages	-24.4	-12.7	-11.8
Textiles	-1.0	0.4	-1.4
Chemicals	-16.4	-1.2	-15.2
Oil production	-35.8	—	-35.8
Other industries	-51.7	-0.4	-51.2
Electricity	-3.8	-10.1	6.2
Water services			—
Construction			—
Other services	-8.8	-11.2	2.4
Transport and communication services	-11.8	-5.9	-5.9
Education and health			—
Trade			—
Total	-152.3	-152.3	-0.0

Source: Own calculations.

Changing the migration "rule" from full rural employment to one based on relative expected income growth will of course not affect the total unemployment numbers. The distribution among urban and rural areas will, however, be altered. With income-generated migration, urban unemployment in the baseline scenario in year 2000 is reduced to 33 percent, while rural unemployment is calculated to be 14 percent. Taking erosion-induced productivity losses into account changes these numbers to 39 and 17 percent, respectively.

5.4.7. Import and export

Table 12 shows the effect on imports and exports measured in (fixed) world market prices. Exports of agricultural products decline, as do imports of non-agricultural products. Imports of maize and beans increase slightly. Considering that domestic production of maize and beans is reduced by approximately 20 percent, it is clear that imports increase their market share considerably.

6. Conclusions

Information on soil loss and the associated loss of productivity is of course highly uncertain. Nevertheless, this model-based study gives evidence for the economic importance of soil erosion in Nicaragua. Furthermore, the economic repercussions of soil erosion are not all trivial in the sense that they only affect the agricultural sectors. Based on the model simulations we find that erosion will affect the sectoral composition of the economic development process quite strongly. Perhaps more surprisingly, we have seen that market power, as in the wage formation process, is important for the assessment of the impact of erosion. In fact, the value of a natural resource like soil is substantially affected by the way wages are determined. Finally, the distributional consequences of excessive soil erosion are more complex than one might at first think. Due to the low price elasticity of demands for basic grains, the rural population that faces the productivity loss due to soil erosion at first hand gets a relative and absolute gain in terms of total real consumption in our—admittedly crude—model simulations. This result implies that soil erosion should be a concern also to other social groups than peasants.

Whether or not these results are believed to be realistic, the model simulation points to the importance of taking linkages like these into account when formulating development strategies. Not only are environmental issues important for long-term economic growth, institutional conditions also determine how valuable environmental and natural resources are to the economy.

Acknowledgements

Appendix A. A computable general equilibrium (CGE) model for Nicaragua

No.	Abbreviation	Name	Agriculture	Rural/Urban	Import	Export
List of sectors (I)						
1	CF	Production of coffee	AGR	R		EX
2	AG	Production of cotton	AGR	R		EX
3	BA	Production of bananas	AGR	R		EX
4	AJ	Production of sesame	AGR	R	IM	EX
5	AZ	Production of sugar	AGR	R		
6	MZ	Production of maize	AGR	R	IM	
7	FR	Production of beans	AGR	R	IM	
8	AR	Production of rice	AGR	R	IM	
9	SG	Production of sorghum	AGR	R	IM	
10	OA	Other agriculture	AGR	R	IM	EX
11	PC	Production of cattle	AGR	R	IM	
12	SV	Forestry		R	IM	EX
13	PS	Fishery		R		EX
14	MN	Mining		R	IM	EX
15	AL	Production of food and beverages		U	IM	EX
16	VT	Production of textiles		U	IM	EX
17	QM	Production of chemicals		U	IM	EX
18	PT	Oil production		U	IM	EX
19	OV	Other industries		U	IM	EX
20	EL	Production of electricity		U	IM	EX
21	AP	Water services		U		
22	CT	Construction		U		
23	SC	Other services		U	IM	EX
24	TR	Production of transport and communication services		U	IM	EX
25	ES	Education and health		U		
26	CM	Trade		U		
Social classes (K)						
1	CP	Campesinos				
2	WK	Urban workers				
3	PR	Urban small proprietors				
4	KP	Capitalists				

A.1. Model equations

1	Composite price:	$PC_i \cdot XC_i = PD_i \cdot XD_i + pm_i \cdot M_i$	$i \in IM$
2	Composite price in non-importing sectors:	$PC_i = PD_i$	$i \in I - IM$
3	Value of sale (gross revenue):	$P_i \cdot X_i = PD_i \cdot XD_i + pe_i \cdot E_i$	$i \in EX$
4	Unit value of sale in non-exporting sectors:	$P_i = PD_i$	$i \in I - EX$
5	Price on capital:	$PK_i = \sum_j PC_j \cdot imat_{ji}$	$i,j \in I$
6	Activity level, exporting sectors CET	$X_i = at_i \cdot \left[\gamma_i \cdot E_i^{\rho_{ei}} + (1 - \gamma_i) \cdot XD_i^{\rho_{ei}} \right]^{\frac{1}{\rho_{ei}}}$	$i \in EX$
7	Activity level, non-exporting sectors:	$X_i = XD_i$	$i \in I - EX$
8	Commodity composition of output:	$\dfrac{E_i}{XD_i} = \left\langle \dfrac{pe_i}{PD_i} \cdot \dfrac{1 - \gamma_i}{\gamma_i} \right\rangle^{\frac{1}{\rho_{ei}-1}}$	$i \in EX$
9	Composite commodities CES:	$XC_i = ac_i \cdot \left[\delta_i \cdot M_i^{-\rho_{mi}} + (1 - \delta_i) \cdot XD_i^{-\rho_{mi}} \right]^{\frac{-1}{\rho_{mi}}}$	$i \in IM$
10	Output in non-importing sectors:	$XC_i = XD_i$	$i \in I - IM$
11	Demand for imports:	$\dfrac{M_i}{XD_i} = \left\langle \dfrac{PD_i}{pm_i} \cdot \dfrac{\delta_i}{1 - \delta_i} \right\rangle^{\frac{1}{1+\rho_{mi}}}$	$i \in IM$
12	Unit cost:	$COST_i = \sum_j PC_j \cdot a_{ji} + W_i \cdot LC_i$	$i,j \in I$
13	Profit:	$GAN_i = \left[P_i \cdot (1 - tv_i) - COST_i \right] \cdot X_i$	$i \in I$
14	Income working class:	$Y_{wk} = \sum_i W_i \cdot LC_i \cdot X_i + er \cdot trxk_{wk}$	$i \in I$
15	Income camposino class:	$Y_{cp} = \sum_i dgc_i \cdot GAN_i$	$i \in R$
16	Income producers class:	$Y_{pr} = \sum_i dgs_i \cdot GAN_i + er \cdot trxk_{pr}$	$i \in U$
17	Income capitalist class:	$Y_{kp} = \sum_i (1 - dgc_i) \cdot GAN_i + \sum_j (1 - dgs_j) \cdot GAN_j + er \cdot trxk_{kp}$	$i \in R, j \in U$
18	Expenditure:	$EXPEND_k = (1 - s_k) \cdot (1 - td_k) \cdot Y_k$	$k \in K$
19	Basic consumption:	$SUB_k = \sum_i csub_{ik} \cdot PC_i$	$i \in I, k \in K$
20	Private consumption (LES):	$PC_i \cdot CD_{ik} = PC_i \cdot csub_{ik} + q_{ik} \cdot (EXPEND_k - SUB_k)$	$i \in I, k \in K$
21	Capital in period $t + 1$:	$KF_{i,t+1} = KF_{i,t} \cdot (1 - depre) + DK_{it}$	$i \in I$
22	Total investments equal savings:	$INV = \sum_k s_k \cdot (1 - td_k) \cdot Y_k + SGOB + er \cdot sfor$	$k \in K$
23	Investment by destination:	$INV = \sum_i PK_i \cdot DK_i$	$i \in I$
24	Sectoral investment:	$DK_i = kshare_i \cdot DKTOT$	$i \in I$
25	Government revenue:	$GR = \sum_i \left[tv_i \cdot P_i \cdot X_i + \frac{tm_i}{1 + tm_i} \cdot pm_i \cdot M_i + te_i \cdot pe_i \cdot E_i \right] + \sum_k td_k \cdot Y_k$	$i \in I, k \in K$
26	Government expenditure:	$GD_i = gshare_i \cdot gdtot0$	$i \in I$
27	Government consumption:	$GR = \sum_i PC_i \cdot GD_i + SGOB$	$i \in I$
28	Marked equilibrium:	$XC_i = \sum_j a_{ij} \cdot X_j + \sum_k CD_{ik} + GD_i + \sum_j imat_{ij} \cdot DK_j$	$i \in I, k \in K$
20	Production:	$X_i = ad_i \cdot b_i \cdot \left[LC_i \cdot X_i \right]^{\alpha_i} \cdot KF_i^{1 - \alpha_i}$	$i \in I$
30	Wage rate:	$W_{i,t} = W_{i,0} \cdot IPC_{wk,i-1} \cdot index_i$	$i \in I$

| 31 | Consumer price index: | $IPC_k = \dfrac{\sum_i PC_i \cdot CD_{ik}}{\sum_i CD_{ik}}$ | $i \in I, k \in K$ |
| 32 | Demand for labour: | $W_i \cdot LC_i = \dfrac{\alpha_i}{1 - \alpha_i} \cdot \frac{GAN_i}{X_i}$ | $i \in I$ |

Total number of equations: 521

A.2. List of variables

Endogenous variables:

CD_{ik}	=	Demand for commodity i by class k
$COST_i$	=	Unit cost of production
DK_i	=	Investment by sector of destination
$DKTOT$	=	Total real investments
E_i	=	Exports of commodity i in local currency
$EXPEND_k$	=	Expenditure on consumption by class k
GAN_i	=	Total profit in sector i
GD_i	=	Government expenditure on commodity i
GR	=	Total income to the government
INV	=	Total nominal investment
IPC_k	=	Consumer price index for class k
KF_i	=	Capital by sector
LC_i	=	Labour per activity unit in sector i
M_i	=	Imports of commodity i in local currency
P_i	=	Output price
PC_i	=	Composite price of domestic and imported commodities
PD_i	=	Price of domestic commodity i
PK_i	=	Price of capital
$SGOB$	=	Government saving
SUB_k	=	Basic consumption by social class
W_i	=	Wage rate
X_i	=	Activity in sector i
XC_i	=	Composite commodity of domestic and imported products
XD_i	=	National production for the domestic market
Y_k	=	Nominal income by class k Total number of variables: 521

Exogenous variables and parameters:

α_i	=	Cost share of labour
γ_i	=	Share parameter in export equation
δ_i	=	Share parameter in creation of composite commodity
ρ_{ei}	=	Transformation parameter in export equation
ρ_{mi}	=	Transformation parameter in import equation
a_{ij}	=	Input–Output coefficient
ac_i	=	Shift parameter in creation of composite commodity
ad_i	=	Shift parameter in Cobb-Douglas production function
at_i	=	Shift parameter in activity equation
b_i	=	Shift parameter due to erosion
$csub_{ik}$	=	Basic consumption
$depre$	=	Depreciation rate of capital
dgc_i	=	Distributional coefficient of profits —farmers
dgs_i	=	Distributional coefficient of profits —producers
er	=	Nominal exchange rate
g	=	Growth rate of population
$gdtot0$	=	Total real government consumption in base year
$gshare_i$	=	Government expenditure coefficient
$imat_{ij}$	=	Conversion matrix from destination to origin in investment
$index_i$	=	Wage indexation rule
$kshare_i$	=	Share coefficient on total investment
ls_0	=	Total labour supply in base year
q_{ik}	=	Budget share of consumption by class
pe_i	=	Price of exports in local currency
pm_i	=	Price of competitive imports in local currency
pwe_i	=	World price on exports in $
pwm_i	=	World price on competitive imports in $
s_k	=	Marginal propensity to consume by class
$sfor$	=	Foreign savings

td_k	=	Direct taxes on income
te_i	=	Tariff rate on exports
tm_i	=	Tax on competitive goods imports
$trxk_k$	=	Transfers from abroad to class k in \$
tv_i	=	Tax on value added

References

Asheim, G.B., 1986. Hartwick's rule in open economies. Can. J. Econ., XIX: 395–402.

Brooke, A., Kendrick, D. and Meeraus, A., 1992. GAMS. A User Guide. The Scientific Press, San Fransisco.

Devarajan, S. and Weiner, R.J., 1991. Natural resource depletion and national income accounting. Unpublished manuscript.

Fox, G. and Dickson, E.J., 1988. What's economic about the economic cost of soil erosion to Canadian farmers? Discussion Paper DP88/3, Department of Agricultural Economics and Business, University of Guelph, Guelph, Ontario.

Hicks, J., 1946. Value and Capital. An Inquiry into Some Fundamental Principles of Economic Theory, 2nd edn. Oxford at the Clarendon Press, Oxford.

INETER, 1983. Uso de suelo. Realización de temas cartograficos a partir de la interpretación de imagenes Landsat. Instituto Nicaraguense de Estudios Terretoriales. Ministerio de Planificación, Managua.

Lal, R., 1987. Effects of soil erosion on crop productivity. Crit. Rev. Plant Sci., 5: 303–367.

Lyles, L., 1975. Possible effects of wind erosion on soil productivity. J. Soil Water Conserv., 30: 279.

Magrath, W. and Arens, P., 1989. The cost of soil erosion on Java: a natural resource accounting approach. Environment Department Working Paper no. 18, The World Bank, Washington D.C.

Marín Castillo, E., 1979. Definiciones y parametros de variables edafologicas. Unpublished paper, Instituto Interamericano de Ciencias Agricolas, Managua.

Marín Castillo, E., 1988. Proyecto de ordenamiento del sistema productivo, Region II. Informe final. Ministerio de Desarollo agropecuario y Reforma agraria (MIDINRA), Dirección general de Agricultura (DGA), Managua.

Marín Castillo, E., 1990. Estudio agroecologico y su aplicación al desarollo productivo agropecuario, Region IV. Informe final. Ministerio de Agricultura y Ganadería (MAG), Dirección general de Tecnología agropecuaria (D.G.T.A), Ordenamiento del Sistema productivo agropecuario (O.S.P.A), Managua.

Marín Castillo, E., 1991. Mapa de Erosión hidrica y eolica del Suelo. ECOT-PAF, Gobierno de Nicaragua, Managua.

Marín Castillo, E., 1992. Estudio agroecologico de la Region III y su Aplicación al Desarollo agropcuario. Agencia Finlandese para el Desarollo internacional (FINNIDA).

World Resources Institute and Tropical Science Center, 1991. Accounts Overdue. Natural Resource Depreciation in Costa Rica. Washington, DC.