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# Soil erosion and economic growth in Nicaragua

**by**

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**Summary**

This report deals with the problem of soil erosion in Nicaragua and its economic implications. Soil loss is proceeding at a rapid rate. In some regions more than 2 cm of topsoil is lost every year. Erosion has both on-site and off-site effects, but in this report we discuss only the on-site effects. The major on-site effect of erosion is a decline in soil productivity. The present situation in Nicaragua is unfavourable for soil conservation efforts. Insecure land tenure, conflict about ownership of land together with credit market failure indicate that a considerable part of current soil loss may undermine future income generation.

We have analysed the macroeconomic effects of the current erosion induced reduction in agricultural productivity by means of a general equilibrium model for the Nicaraguan economy. We find that after a period of 10 years, gross domestic product (GDP) and private consumption are reduced by 14.5 and 13.7 percent respectively compared to a baseline scenario without productivity loss. Investment is reduced by almost 24 percent. Production in the agricultural sectors is reduced due to both direct and indirect effects through interaction with the rest of the economy. Sesame, beans and maize experience the largest reductions in production. Production in non-agricultural sectors is also reduced because rising food prices and wage level increases the general domestic cost level. Demand for labour in the formal sector decreases by 25 percent.

At the outset, the basis for making an integrated economy-environment analysis is weak. This is valid in most countries, as the statistics on the environment first has to be established. In Nicaragua, also the modelling of the national economy is in its beginning. However, the early creation of a framework for an integrated 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. Like many other developing countries, Nicaragua is today facing an economic crisis that makes a dialogue on long term environmental problems difficult to sustain.

However, an integrated analyses might contribute by illustrating that environmental protection can increase traditionally measured economic growth, as may be the case in Nicaragua where the natural production capital is degrading rapidly.

## 1. Introduction

Agriculture has an important position in the economy of Nicaragua. 25-30 percent of the gross domestic product is generated in this sector, occupying around half the working population. Export crops provide roughly 70 percent of foreign exchange (INEC, 1991). The strategy for development of the agricultural sector is important, because the country has rich soil resources and the present technology is inefficient, leaving a considerable potential for growth.

Unfortunately, the fertile soils of Nicaragua are threatened by erosion. Erosion is loss of soil by flooding or wind (further discussed in part 2.1). The rate of erosion depends on several natural conditions like soil type, climate/rainfall and topography. However, the prevailing social and economic conditions are also important for determining the degree of erosion.

Nicaragua has large plains with fertile, volcanic agricultural land on the north-western Pacific coast. In the 1950's and 60's, during a period of rapid expansion of export crop production, in particular of cotton and livestock production, small-scale farmers were expelled from the lowlands to hilly areas for subsistence cultivation of mainly maize and beans. Two aspects make this event critical for soil degradation. The peasants continued to apply their traditional lowland technology to steep terrains where they primarily grow basic grains like maize and beans. Annual crops like maise and beans expose the soil to erosion to a higher degree than forest and perennial crops. This accelerated the process of soil degradation in Nicaragua. Also, population growth increased the pressure on these vulnerable parts of the land. According to Blaikie (1985), many developing countries have experienced similar migration due to the same causes and with the same consequences in terms of soil degradation.

In Nicaragua, soil degradation has been studied on a national level (Marin, 1991). 33 percent of the agricultural land is moderately to seriously degraded by hydrological erosion. On hilly hinterlands in central Nicaragua where maize and beans are cultivated, continued use of prevailing technology might ruin land productivity within 2-3 decades.

As in most cases concerning soil quality and management, the information on erosion is developed and presented on maps. This is convenient when considering soil conservation measures directed at a local farming level. But, a problem with maps is that they are difficult to use when decisions concerning general economic policy and laws are to be taken. These decisions do have an impact on erosion, but to what extent? Due to the lack of information about the links between economic policy in general and the degradation of soil resources, the erosion problem is usually neglected within the context of economic policy decision making.

This paper describes an attempt to include the interrelation between soil erosion and economic activity as described in an applied general equilibrium (AGE) model for Nicaragua. In this model, 12 agricultural activities are specified. Land use is currently degrading the soil and economic forecasting will overestimate future growth if no adjustments are made for declining productivity. Annual productivity loss by sector (crop) is assessed and more realistic growth perspectives are generated.

Also, the scale of erosion measured as soil loss in tons is estimated within the model framework. Land use represented by output of different crops is broken down on regional levels to account for variations in soil characteristics, topography and climate. The soil loss is estimated as a linear function of land use by region.

The AGE model was developed at Instituto Centroamericano de Administración de Empresas (INCAE). A version incorporating soil erosion was developed in cooperation between INCAE and the Central Bureau of Statistics of Norway (CBS), funded by The Norwegian Agency for Foreign Cooperation and Development (NORAD).

The report is organized as follows: Section 2 contains a brief introduction to soil erosion and some reasons why soil conservation measures usually are not implemented. Section 3 focuses on some important reasons for linking environmental aspects to macroeconomic policy, while section 4 comments on a few studies dealing with the cost of soil erosion on a national level. Then follows a description of the erosion problem in Nicaragua (section 5). The environmental submodel for soil loss is described in section 6. The general equilibrium modelling framework is presented in section 7. Finally in section 8 we describe the simulations of the macroeconomic effects of a reduction in productivity due to erosion.

## 2. Soil erosion

Soil erosion can be defined as detachment and removal of soil by wind and moving water. In this process, the structure of the soil is normally deteriorated. It is common to distinguish between on-site and off-site effects of erosion. On-site effects refer to the effects where soil is removed. Off-site effects involves the impact of soil depositions such as clogging of waterways, pollution, and siltation and increased flooding of lower land. This work is limited to analyses of the on-site 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. 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 create a structure of macropores for the water to infiltrate. In addition, litter, roots and stems impede the water speed, 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. Clearing forests initiates rapid erosion. In addition to rainfall, other natural factors affect the erosion rate. Steep land accelerate the surface flooding, and soil consisting of fine particles (loam, silt) are more easily eroded than coarse 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 has been drastically increased by intensified agricultural activity. Under undisturbed vegetation there is normally a balance between soil erosion and the soil formation processes. Cultivation of the land usually interrupts this balance, because the vegetation cover is reduced. Consequently, erosion will often increase beyond the soil formation rate under cultivation (accelerated erosion). According to Lal (1987), the current rate of global erosion is roughly 10 times higher than the natural rate.

The amount of soil and characteristics of the soil profile decides how fast soil loss affects the productivity of land. Lal (1987) gives an overview of variables determining erosion and erosion induced productivity losses.

### 2.2 Soil loss and productivity loss

The on-site economic impacts of soil loss is due to yield reductions. There are several factors that can make soil productivity fall. In the following, we briefly mention some dominant hypothesis, 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 this 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. In the U.S., The National Soil Erosion - Soil Productivity Research Committee (1981) concluded that the main reason for productivity loss by erosion is loss of plant-available soil water. As the topsoil is lost, the subsoil is exposed. This soil normally has poorer structure and is more compact. *Water infiltration capacity is reduced*, which in turn may lead to increased surface runoff and accelerated erosion. Consequently, erosion increases the frequency, duration and intensity of drought.

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 nutrients 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 generate floods, and the water storage capacity is a limiting factor in dry periods.

### 2.3 Barriers to erosion control

Through runoff of soil and water, the farmer looses productivity of his land. In addition, the erosion can have negative impact on the productivity on farming in lower areas due to increased seasonal surface flooding. Erosion also has negative off-site effects due to soil deposits in waterways. It is easy to see that an individual farmer has no incentive to care about the off-site erosion costs, but why is he not engaged in soil conservation to prevent degradation of his own land and income potential? There are several reasons that may explain such a behaviour. 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 practise.

- Soil degradation is a cumulative process, implying relatively small year to year changes. These are hard to detect when crop yields in any case vary considerably due to management, plagues, precipitation and other factors. 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, fertilizer and pesticides were strongly subsidized during the 1980's. 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 that 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 recent past, peasants were forced to leave the land that were occupied by big landowners for export production. During the contra war, hundred thousands of people fled from 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 after 1990 has cut down on credit to small peasants usually short of liquidity, reducing their potential to produce and generate income even when an income potential is present. Thus, a likely outcome of the current credit shortage might for many peasants be to abandon the land.

- The credit shortage 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 the prevailing cultivation practice. However, perennial crops will not produce yields until after several years. 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.

## 3. Integrating macroeconomic and environmental policy

Nicaragua is facing an accelerated deforestation which if continued at the present rate could eliminate the forest resources within the next 30 years. Also, widespread application of unsustainable techniques in agricultural production degrade the future resource base. According to the Medium-term Development Strategy 1992-1996 for Nicaragua (Government of Nicaragua, 1992) the driving forces behind the deforestation are 1) the lack of alternative use of forest resources, 2) low productivity in the campesino agriculture, 3) land tenure instability and 4) the lack of employment opportunity in other sectors. In various ways, the degradation or conservation of forests and soil is interwoven with the institutional framework and general economic policy.

In section 2.3 we discussed how small farmers may perceive and respond to the erosion problem and how institutional factors like insecure land tenure and distortions in the credit market may undermine improvements in soil management. The relationship between prices on agricultural products and land management is also important. Prices determine the income from cultivation of different crops on a particular site. The farmers select crop and technology based on information on prices. Perennial crops (coffee, fruit trees) are less erosive than annual crops (maize, beans, root crops). Consequently, product prices and production costs affect the rate of erosion. Furthermore, the prices that directly determine the income in agricultural sectors depend on the whole price vector of the economy. The exchange rate is an important price influencing the profitability of export crops. The alternative cost of labour affects labour intensive crops more than others.

Also, any measure to deal with the erosion problem transforms the economic picture by introducing new technologies and associated level of costs. A new equilibrium including appropriate soil conservation technologies, will reflect the change in use of input factors, including land, agrochemicals and labour. It turns out that any regulations or pricing policy, tax policy or environmental policy has impact on the loss of soil and in turn on the growth potential. These linkages are the main reason for integrating land erosion within a framework of an economic model.

Deforestation is closely linked to the erosion problem, initiating rapid erosion in fragile areas and increasing the surface flooding in lower areas. Migration to agricultural frontiers is a phenomenon which is closely related to the general income level and the alternative employment opportunities. Low wages encourage clearing of land. On the other hand, available virgin land by itself is an employment alternative, moderating a fall in wages in the formal sector when there is surplus of labour. Thus, large scale migration to the frontier contributes to keep up the cost of labour in the rest of the economy. Deforestation clearly interacts with the development of the national economy and should ideally be studied as a functional part of it. Due to lack of data, this study is unfortunately not covering the special aspects of deforestation.

One of the advantages of using a macroeconomic model as a basis for this kind of analysis is that it takes into account indirect effects and not only the direct effects. This implies that the effect of policies directed at other sectors than the agricultural sector, but which influence activity levels in the agricultural sectors, are included in the analysis. By stimulating production in the manufacturing sectors, demand for agricultural products will also increase. The mechanisms in the general equilibrium model will ensure that these effects are taken into account.

The National strategy plan (Government of Nicaragua, 1992) explicitly says that the economic policy should take into account the impact on the environment. However, so far there exists no system of information relating national economic policy for Nicaragua to the environment in quantitative terms.

At the outset, the basis for making integrated economy-environment analyses is weak. This is valid in most countries, as the statistics on the environment first has to be established. In Nicaragua, also the modelling of the national economy is in its beginning. However, the early creation of a framework for an integrated 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 crisis like that of Nicaragua today make a dialogue on rather long term environmental problems difficult to sustain. However, an integrated analyses might contribute by illustrating that environmental protection can increase traditionally measured economic growth, as may be the case in Nicaragua where the natural production capital is degrading rapidly.

In this report we link soil loss and soil productivity to a model of economic activity and underlying policy decisions. The purpose is to provide a basis for a more comprehensive approach to studies of growth strategies for Nicaragua in the light of these feedbacks from the environment to the economy.

## 4. Economic development and erosion

Erosion is enhanced by credit market failures and absence of a secure land tenure regime characteristic of many less developed countries. Erosion may in turn undermine development efforts. Typically, erosion represents an inherent negative technological change in the production performed by the poorest part of the population who live on the most fragile land. This may contribute to sustain widespread poverty, holding a considerable part of the population below a life standard which is more favourable for generating progress. Erosion is one of the factors nourishing poverty by limiting access to food, health service and education which play a dynamic role in the development process. Any marginal cost can be critical when pushing thresholds to more rapid growth further out in time. But how big is the erosion problem, disregarding the critical level subsistence farmers operate on? The question gets all kinds of answers. As Blaikie wrote in "The political economy of soil erosion",

> There are some leading opinions which claim that soil erosion, although perhaps widespread, is not important, and that "induced innovations" by farmers, governments and private sector research and development institutions will cope. These opinions seem so diametrically opposite to many others which claim that erosion is widespread and serious that the problem arises over how to judge the issue. (Blaikie, 1985)

This study can only very indirectly contribute to close this perception gap. We focus at the economic implications of soil erosion. Highlighting the values at stake might stimulate effort in further - and perhaps more coordinated - soil studies.

Few attempts have been made at quantifying the cost of erosion at a national level. This is partly due to lack of adequate data on erosion and the associated fall in productivity. Also the difficulties of making such cost estimates are increased by the lack of communication between soil specialists focusing on differences in erosion between neighbour plots and economists in need of data relevant to policy decisions at a national level. As background for the results for Nicaragua provided later in this report, we refer below to some nation-wide or regional studies of yield loss or soil erosion costs. The results can, however, not be directly compared with each other or with the results we obtained in the case of Nicaragua, since soil, cultivation technology and natural conditions may differ considerably. Also, the economic assements apply different approaches.

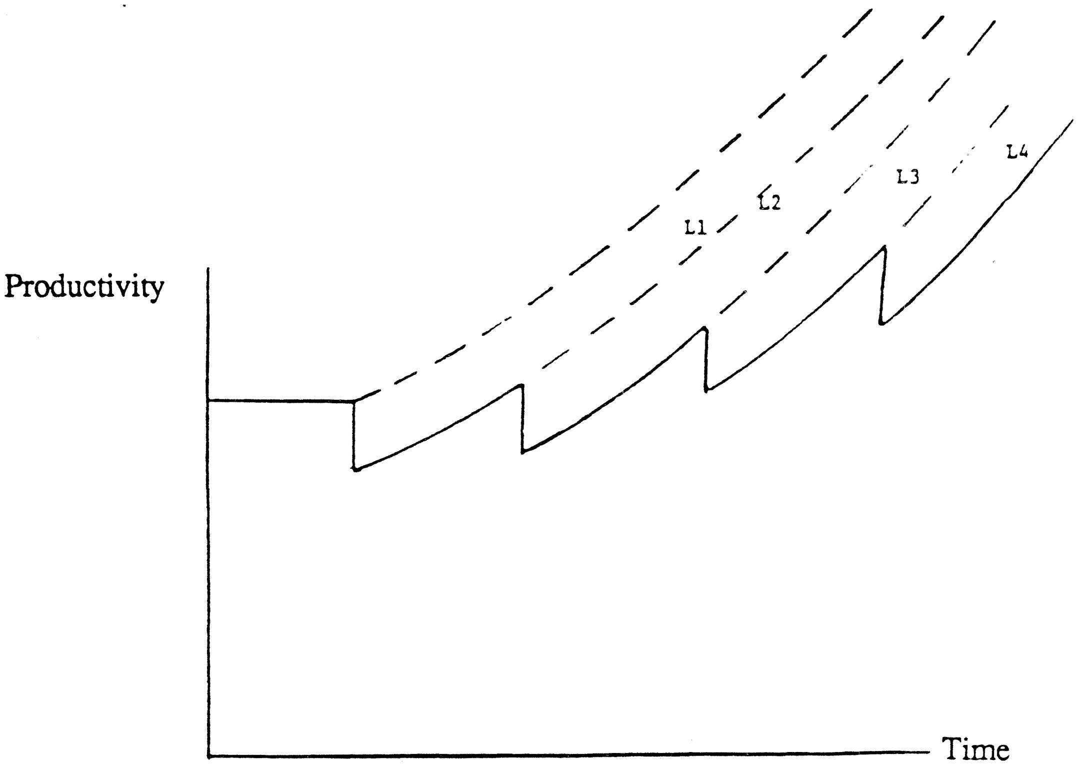
### 4.1 Erosion cost assessments

In Costa Rica, an assessment of national soil depreciation was made as part of developing natural resource accounts (World Resources Institute, 1991). The study estimated the soil loss and the cost of replacing the equivalent amount of nutrients (nitrogen (N), phosphorus (P) and potassium (K)). The soil loss estimates were built upon the universal soil loss equation (USLE) (Wischmeier and Smith, 1978) adjusted to the soil characteristics (erodibility, slope) (Vásquez, 1989) and rainfall (Vahrson, 1989) of Costa Rica. It turned out that the replacement costs of annual soil loss amounted to between 6 and 13 percent of gross product in the agricultural sector over the years from 1970 to 1989. Of the accumulated soil loss in this period, 61 percent occurred on land with annual crops, 5 percent on land with perennial crops and 34 percent on pasture. The distribution of land use on the above categories was roughly 15 percent, 10 percent and 75 percent respectively. As discussed in the report, the cost of replacing the loss of nutrients does not reflect the true soil capital loss, defined as future income reduction from diminished soil productivity.

Because maize is an important annual crop in Nicaragua, we refer to a study by Lyles (1975) who surveyed the decline in maize yields due to soil erosion in different states in the Corn Belt of Midwestern U.S. Yield reductions ranged from 1.7 to 3.5 percent per centimeter of topsoil loss. However, according to Lal (1987), these estimates are low compared to similar information on the effects of soil erosion in the tropics.

Magrath and Arens (1989) assessed soil loss and productivity loss on Java. The productivity loss was estimated for different crops and regions. For maize, soybeans and groundnuts, the annual fall in productivity from loss of topsoil was estimated to be between 2 and 15 percent over a range of 15 to 600 tons soil loss per hectare (roughly equivalent to 0.15 to 6 cm loss of topsoil). The annual productivity loss for different regions weighted by area of different cropping systems varied between 3.8 and 4.4 percent. Such rates of productivity loss probably matters to the development of agriculturally based economies.

**Figure 4.1. Productivity loss due to erosion.**




Impact of Technical Change on Cost of Erosion

Figure 4.1. from Magrath and Arens (1989) illustrates how technological improvement increases the cost of erosion on cultivated land. Erosion repeatedly brings negative shifts in the overall rising productivity of labour, capital and intermediates. As productivity of these input factors increases, the gap between income with and without a given amount of soil will also widen. Each year the value of soil capital is reduced by the discounted future income gap. In Nicaragua right now, low income is earned while the soil is degrading rapidly. How big the soil capital loss is, depends on the future capability to generate income from the soil. To determine the cost of soil erosion it is necessary somehow to foresee future development. We need a model to compare scenarios with and without soil erosion.

## 4.2. Consistent erosion cost estimates.

Often, the cost of soil erosion is associated with reduction in crop yields related to the actual land use when compared to an alternative situation where soil is undisturbed by erosion. However, the zero erosion scenario is hardly feasible in technical terms, and not even attractive in economic terms due to the cost of implementing it. Fox and Dickson (1988) point at several erosion cost studies where the cost of cultivating the soil sustainably is not taken into account.

The soil depreciation estimates for Costa Rica (World Resources Institute, 1991) refer to an alternative scenario different from the zero erosion case, but in an inconsistent way. When nutrient replacement costs were calculated, a hypothetical sustainable erosion level (equal to regenerated soil under best management of various soil types) was first subtracted from the estimated physical soil loss. However, the alternative cost of practising this soil management was not considered. Thus it was not taken into account that an alternative agricultural practice would reshape the whole economy, also the prices (on crops, fertilizer, labour) and land use pattern by which the soil depreciation costs were estimated.

Devarajan and Weiner (1989) provide estimates of genuine erosion costs in Mali. They first estimate the extent of yield reductions associated with the current rate of erosion. Next they introduce a soil conservation demand curve, which may be interpreted to reflect perfect foresight as to future income possibilities. Assuming a constant marginal cost of soil conservation, the extent of excessive erosion is determined. It turns out that roughly 1/4 of the land degradation and related yield reduction represents a depreciation of soil capital in the sense that it undermines future income generation. Soil depreciation in Mali was estimated to be 0.36 percent of GDP and 0.91 percent of agricultural GDP in 1988.

The study of Devarajan and Weiner is consistent in the sense that the costs of sustainable cultivation are incorporated. However, in the two stage procedure used by Devarajan and Weiner, the soil conservation demand curve as well as conservation cost curve is invariable with respect to the general state of the economy and the agricultural activity. It is doubtful that this de-linkage will hold for agriculturally based economies like most developing countries. In particular soil conservation supply may be heavily based on labour and fertilizers and thus sensitive to their costs. To the extent that these costs determine the structure of the agricultural sector, there is a feedback from soil conservation to agricultural production.

Large scale soil conservation will demand resources and affect relative prices and income generation in the whole economy. Also, the equilibrium will shift due to the current soil degradation (on 3/4 of the land in Mali) which is not excessive, but affects the productivity. Thus the base year prices and activity levels are improper for estimating forgone income due to erosion. To deal with this problem, we need a model describing the impact of degradation on productivity, land use and prices.

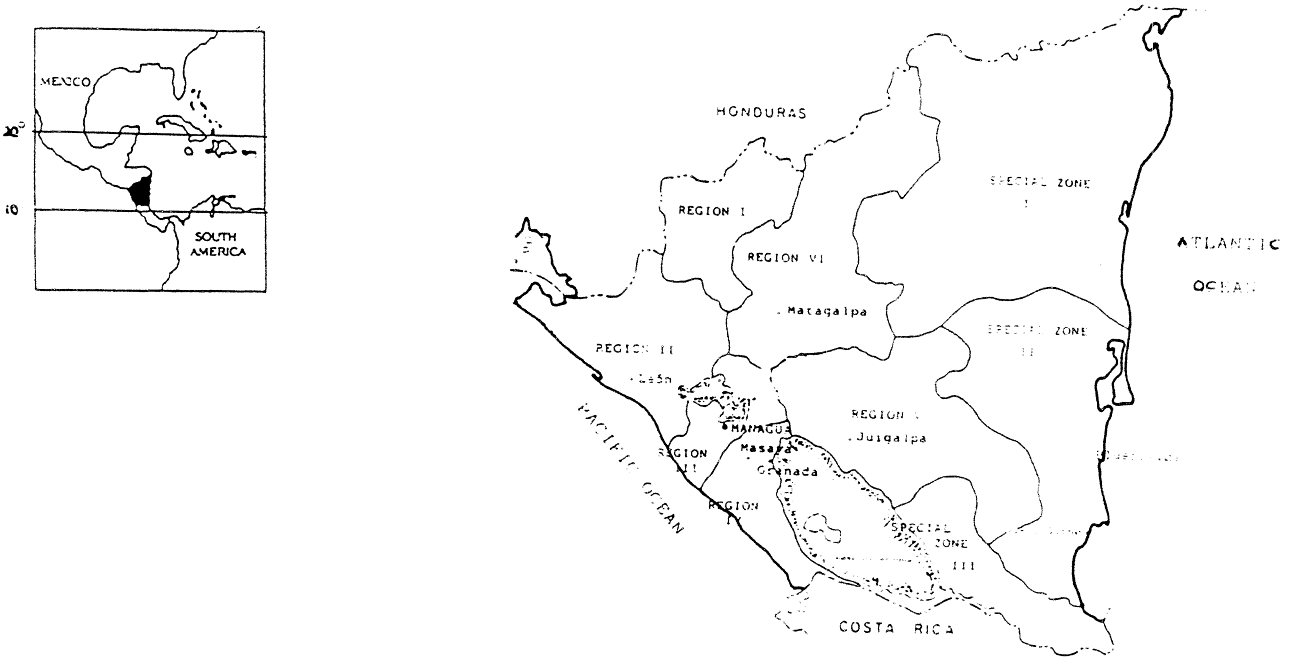
In general, soil conservation is not costless. However, different crops expose soil to various degrees. Soil conservation up to a certain point could be realized costless by switching to a different cultivation pattern. The current land use is a result of market failure. If soil depreciation costs were considered, more erosion-resistant crops would be grown. In Devarajan and Weiner (1989) all land use is assumed to be homogenous as to soil loss and productivity loss. Within this framework, soil capital benefits of restructuring the agricultural production is left out. These are among the aspects we try to include in our study by linking soil degradation to crop production in a multi-sector general equilibrium model.

## 5. Soil erosion in Nicaragua

### 5.1 General description of the country and the agricultural activity

Administratively, Nicaragua is divided into 6 regions and 3 special zones as illustrated on the map in figure 5.1. The majority of the population and the economic activity is located in the 6 regions, although the three special zones contain most of the land area. Except for some production of basic grains, the value of the agricultural production in the three special zones is insignificant, and 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 3 special zones in this work.

**Figure 5.1. Administrative map of Nicaragua.**




Located 10-15$^0$ north of equator, the climate in Nicaragua is tropical to sub-tropical with even temperatures the year round. Within the 6 administrative regions, precipitation ranges from a little below 1 000 mm up to 2 000 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 6 administrative regions into two parts; the Pacific coast (comprising the administrative regions II, III, and IV) and the Central region (comprising Region 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 in the cotton production, expanding on the flat plains of León and Chinandega in region II from the 1950's and on to the 1970's. In Region III, the fertile soils are located to more rugged and elevated terrains, making coffee the most important product. Region IV is the agriculturally most diversified 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 6 regions in livestock production. Except for the lower parts of region V, and some valleys in region I and VI, the Central region is largely mountainous, providing a cooler climate and a more rugged terrain than in rest of the country. The soils are generally fertile, but of older origin and less erodible than the soils along the Pacific coast. The importance of the various products is indicated in table 5.1, which shows average area harvested by region in the two decades 1970-80 and 1980-90.

**Table 5.1. Average area harvested annually. 1 000 hectares**

| | Region I | | Region II | | Region III | | Region IV | | Region V | | Region VI | | Nicaragua | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 70's | 80's | 70's | 80's | 70's | 80's | 70's | 80's | 70's | 80's | 70's | 80's | 70's | 80's |
| Beans | 14 | 19 | 1 | 4 | 2 | 2 | 9 | 12 | 5 | 17 | 21 | 24 | 52 | 78 |
| Maize | 22 | 21 | 33 | 21 | 7 | 4 | 20 | 15 | 29 | 52 | 56 | 58 | 168 | 171 |
| Sorghum | 7 | 4 | 12 | 19 | 11 | 12 | 8 | 15 | 5 | 5 | 7 | 4 | 50 | 58 |
| Rice | 1 | 2 | 2 | 8 | 3 | 1 | 7 | 9 | 5 | 9 | 3 | 4 | 21 | 34 |
| Sesame | .. | .. | 6 | 13 | 0 | 1 | 2 | 2 | .. | .. | .. | .. | 9 | 16 |
| Coffee | 19 | 15 | 1 | 1 | 18 | 9 | 30 | 13 | 3 | 4 | 63 | 40 | 133 | 81 |
| Cotton | .. | .. | 112 | 68 | 10 | 3 | 8 | 5 | .. | .. | .. | .. | 130 | 76 |
| Sugar | 1 | 0 | 22 | 23 | 5 | 7 | 6 | 8 | .. | .. | 2 | 1 | 36 | 39 |
| Total | 64 | 62 | 190 | 157 | 56 | 39 | 90 | 78 | 47 | 86 | 153 | 131 | 599 | 553 |

Source: Ministry of Agriculture

The most significant change from the 1970's to the 1980's is the expansion of basic grains, and the reduction in the harvested area of cotton and coffee, traditionally the two most important export crops. Credit to small scale peasants, the main producers of basic grains, were introduced in the 1980's and eased the expansion of area for basic grain production. The harvesting of coffee suffered during the 1980's because of the war, while the reduction in cotton primarily is caused by lower profits due to ecological problems of erosion, increasing costs of plant protection and falling prices on the world market. In 1991, the area sown with cotton was 1/5 of the area cultivated in 1977 (Banco Central 1991).

The cultivated area in the Central region increased, especially in Region V, while on the Pacific coast the cultivated area shows a slight decline. But also in the Pacific coast, the area with basic grains increased.

During the 70's and 80's the use of chemical fertilizer increased, especially in the production of basic grains. Table 5.2. shows the change in yields from the 1970's to the 1980's.

**Table 5.2. Change in average yields from the 1970's to the 1980's. Percent.**

| | Region | | | | | |
|---|---|---|---|---|---|---|
| | I | II | III | IV | V | VI |
| Beans | 6 | 0 | 9 | 8 | -6 | -6 |
| Maize | 121 | 79 | 110 | 76 | -6 | 17 |
| Sorghum | 38 | 30 | 42 | 55 | 36 | 46 |
| Rice | 32 | -11 | 22 | 19 | -9 | 0 |
| Sesame | -20 | -27 | -9 | -18 | .. | .. |
| Coffee | 65 | 3 | -15 | 47 | -6 | 94 |
| Cotton | .. | -5 | 4 | 0 | .. | .. |
| Sugar cane | 25 | -10 | 2 | -3 | 8 | 45 |

Source: Ministry of Agriculture

Table 5.2 shows that maize and sorghum has experienced the largest increase in yields during the period. The increase in yields for sorghum is more or less the same for all regions while maize experienced a decline in yields in Region V and just a moderate increase in Region VI. Yields for sesame have decreased during the period in all regions. For the other crops the picture is a bit more mixed with yields going up in some regions and down in others.

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

The Applied General Equilibrium model (AGE-model) for the Nicaraguan economy describes the agricultural activity in 12 different sectors. Since both production and agroecological conditions vary geographically, generating unequal rates of soil degradation, we have organized and related the information on soil erosion both to production and region. The erosion indexes and the indexes for erosion induced decline in soil productivity are specified for the 6 administrative regions and 11 agricultural production activities (erosion data for the activity "Other agricultural products" are not available. However, the area used for these crops is insignificant.)

The primary data source for the erosion estimates is the erosion map of Nicaragua in the scale of 1:522 000 published by the government of Nicaragua (Marín, 1991). A more aggregate version of the erosion map is given in appendix 1. The cultivated land is classified according to 6 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 (Marín, 1979). The definitions are shown in table 5.3. Based on an average depth of the A horizon of 40 cm and the B horizon of 50 cm, the corresponding soil loss depth in cm is also shown.

**Table 5.3. Definitions of the 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 |

Below we describe the process of estimating annual soil erosion and rates of erosion induced productivity loss. The distribution of land on erosion classes is shown i table 5.4. Basic information behind this distribution is the erosion map (Marín, 1991) and a land use map (INETER, 1983). The state of erosion by crop, area and region was assessed. However, on the basis of various soil studies (Marín 1988, 1990, 1992) the erosion status by these land categories was assessed more accurately within the erosion class intervals as specified in table 5.3. Instead of characterizing an erosion class by lower limit, upper limit or the average, subjective evaluations are included by direct assessments of the state of erosion in an area. Table 5.5 shows the resulting estimates of accumulated soil loss in tons/hectare [1] in 1970, 1980, and 1990. This may seem somewhat elaborate, but is made in this manner to explicitly show assessments and calculations stepwise.

[1] The units were converted from % of profile to tons/hectare by assuming that 1 cm soil corresponds to 100 ton/hectare (a density factor of 1 ton/m3). In this way, table 5.1. could be applied to all of Nicaragua. In reality, the soil density varies, but using a single conversion factor is justified by the fact that, roughly speaking, the land with the deeper soils generally consist of soils lighter than 1 ton/m3 (light volcanic soils density 0,8 - 0,9 tons/m3), while in the areas containing shallower soils, the density is generally higher than 1 ton/m3.

## Table 5.4. Land use by region, crop and erosion class. Percent.

| | Region I | | | | | | Region IV | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Light | Moderate | Strong | V.strong | Severe | Extreme | Light | Moderate | Strong | V.strong | Severe | Extreme |
| Beans | 25 | 35 | 20 | 20 | | | 40 | 30 | 30 | | | |
| Maize | 25 | 35 | 20 | 20 | | | 30 | 40 | 30 | | | |
| Sorghum | 20 | 40 | 40 | | | | 30 | 40 | 20 | 10 | | |
| Rice | 50 | 30 | 20 | | | | 75 | 25 | | | | |
| Sesame | 20 | 50 | 30 | | | | | 40 | 40 | 20 | | |
| Coffee | 25 | 40 | 35 | | | | 30 | 30 | 30 | 10 | | |
| Cotton | | | | | | | 15 | 30 | 25 | 20 | 10 | |
| Sugar | 40 | 40 | 20 | | | | 80 | 10 | 10 | | | |
| Tobacco | 70 | 30 | | | | | 50 | 30 | 20 | | | |
| Vegetables | 90 | 10 | | | | | | | | | | |
| Pasture | 10 | 20 | 30 | 30 | 10 | | 30 | 25 | 25 | 20 | | |

| | Region II | | | | | | Region V | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Light | Moderate | Strong | V.strong | Severe | Extreme | Light | Moderate | Strong | V.strong | Severe | Extreme |
| Beans | 25 | 45 | 30 | | | | | 50 | 40 | 10 | | |
| Maize | 20 | 50 | 30 | | | | | 50 | 40 | 10 | | |
| Sorghum | 30 | 40 | 20 | 10 | | | | 40 | 30 | 20 | 10 | |
| Rice | 50 | 30 | 20 | | | | | 100 | | | | |
| Sesame | 10 | 20 | 30 | 30 | 10 | | | 20 | 40 | 40 | | |
| Coffee | 10 | 60 | 30 | | | | | 30 | 40 | 30 | | |
| Cotton | 20 | 30 | 30 | 10 | 10 | | | | | | | |
| Sugar | 70 | 30 | | | | | | | | | | |
| Tobacco | 80 | 20 | | | | | | | | | | |
| Vegetables | | | | | | | | | | | | |
| Pasture | 50 | 30 | 20 | | | | 40 | 20 | 20 | 10 | 10 | |

| | Region III | | | | | | RegionVI | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Light | Moderate | Strong | V.strong | Severe | Extreme | Light | Moderate | Strong | V.strong | Severe | Extreme |
| Beans | | 35 | 35 | 30 | | | 15 | 40 | 20 | 20 | 5 | |
| Maize | | 40 | 40 | 20 | | | 15 | 40 | 20 | 20 | 5 | |
| Sorghum | 15 | 30 | 30 | 25 | | | 30 | 30 | 20 | 20 | | |
| Rice | 90 | 10 | | | | | 80 | 10 | 10 | | | |
| Sesame | | 30 | 30 | 40 | | | | | | | | |
| Coffee | 15 | 40 | 25 | 15 | 5 | | 20 | 30 | 25 | 15 | 5 | 5 |
| Cotton | 10 | 40 | 30 | 10 | 10 | | | | | | | |
| Sugar | 70 | 30 | | | | | 30 | 40 | 30 | | | |
| Tobacco | | 80 | 20 | | | | 100 | | | | | |
| Vegetables | | | | | | | 70 | 15 | 15 | | | |
| Pasture | 60 | 10 | 10 | 10 | 5 | 5 | 10 | 15 | 25 | 25 | 20 | 5 |

**Table 5.5. State of erosion by erosion class, region and crop. 1970, 1980, and 1990. Accumulated soil loss. Tons/hectare.**

| Production | Region | Erosion class | Accumulated soil loss 1990 | 1980 | 1970 |
|---|---|---|---|---|---|
| Coffee | I | Light | 500 | 300 | 200 |
| | | Moderate | 1200 | 700 | 400 |
| | | Strong | 2000 | 1200 | 700 |
| | III | Moderate | 1800 | 1000 | 600 |
| | | Strong | 2800 | 1500 | 800 |
| | | Very Strong | 4000 | 2000 | 1000 |
| | | Severe | 5500 | 3000 | 1500 |
| | IV | Light | 700 | 400 | 200 |
| | | Moderate | 1500 | 900 | 500 |
| | | Strong | 2500 | 1500 | 800 |
| | | Very Strong | 3500 | 2000 | 1000 |
| | V, VI | Light | 800 | 500 | 250 |
| | | Moderate | 1700 | 1000 | 600 |
| | | Strong | 2800 | 1600 | 1000 |
| | | Very Strong | 3500 | 2000 | 1200 |
| Cotton | II | Light | 1000 | 400 | 250 |
| | | Moderate | 1500 | 800 | 500 |
| | | Strong | 2500 | 1400 | 800 |
| | | Very Strong | 3500 | 2000 | 1300 |
| | | Severe | 5500 | 3000 | 2000 |
| | IV | Light | 1000 | 400 | 250 |
| | | Moderate | 1700 | 900 | 500 |
| | | Strong | 3000 | 1600 | 1000 |
| | | Very Strong | 4000 | 2300 | 1500 |
| | | Severe | 6500 | 3500 | 2200 |
| Sugar cane | II, III, IV | Light | 600 | 300 | 200 |
| | | Moderate | 1200 | 700 | 400 |
| Banana | II | Light | 600 | 300 | 200 |
| | | Moderate | 1000 | 600 | 300 |
| Rice, upland | I, II | Light | 1000 | 500 | 300 |
| | | Moderate | 1500 | 800 | 400 |
| | | Strong | 2000 | 1400 | 800 |
| Rice, irrigated | I - VI | Light | 500 | 300 | 150 |
| Sorghum | II, IV | Light | 1000 | 400 | 250 |
| | | Moderate | 1500 | 750 | 500 |
| | | Strong | 2500 | 1400 | 750 |
| | | Very Strong | 3500 | 2000 | 1250 |
| | | Severe | 5750 | 3000 | 2000 |
| All other | I - VI | Light | 1000 | 500 | 300 |
| | | Moderate | 2000 | 1000 | 600 |
| | | Strong | 3000 | 1600 | 1000 |
| | | Very Strong | 4000 | 2300 | 1500 |
| | | Severe | 6500 | 3500 | 2300 |

The state of erosion reported in table 5.5 was further aggregated over erosion classes to characterize the state of erosion by crop and region, weighted according to land distribution (table 5.4). Table 5.5 shows that the erosion rates increased substantially from the 1970's compared to the 80's. The reasons for this can be found in the following:

- Large areas of land were handed over to people with little experience in farming for the purpose of subsistence production. With the common systems of production used in Nicaragua, subsistence farming is very erosive. Large areas were clear cut, and tillage practice often included ploughing.

- Around 15 000 tractors were distributed to farmers and cooperatives. Many of those who received the tractors were ignorant to their proper use. Vulnerable soils were tilled at improper times. The machines also brought on compaction of the soil, increasing surface runoff and erosion.

- The ministry of agriculture (MIDINRA) and the state bank that provides agricultural credits (Banco Nacional de Desarollo) encouraged the production of cotton on very erodible land.

- In Carazo in region IV, trees were removed in areas of extensive coffee production.

Table 5.6 shows the average annual soil loss over the period 1981-1990 .

**Table 5.6. Average annual erosion 1981-1990 by crop and region. Tons/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 |

Next, a relation between erosion class, and erosion induced productivity loss was assessed. An important basis for this evaluation was the yield development by crop and region over the last 25 years (appendix 2). Total yield decline by crop, and erosion class in 1990 compared to uneroded soil was assessed as shown in table 5.7. When taking into account that cultivation and associated soil degradation has taken place over different time periods (table 5.5.) the average annual productivity loss by crop and region between 1981 and 1990 was estimated to be as shown in table 5.8 (table 5.8). (National average productivity loss indices (by crop, aggregated over regions) are shown in table 8.1.)

**Table 5.7. Erosion induced yield declineby region, crop and erosion class. Percent productivity compared to uneroded soil. 1990.**

| | Light | Moderate | Strong | Very | Severe | Extreme |
|---|---|---|---|---|---|---|
| Maize | 100 | 80 | 56 | 34 | 17 | 7 |
| Coffee | 100 | 85 | 68 | 51 | 36 | 23 |
| Coffee | 100 | 90 | 77 | 61 | 46 | 32 |
| Pasture | 100 | 100 | 70 | 39 | 15 | 6 |
| All other | 100 | 85 | 68 | 48 | 29 | 14 |

The relation between erosion class and erosion induced productivity loss displayed in table 5.7 is based on qualified assessment. We do not know of Nicaraguan investigations on the effects of erosion on yields. It should also be kept in mind, as mentioned in section 2.2, that yield levels are influenced by a number of intervowen factors, and it is difficult to isolate the effects of erosion.

**Table 5.8. 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 | 2,7 |
| 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 |

Table 5.8 shows that beans, maize, sesame and pasture are the sectors that experiences the largest productivity loss due to erosion. For beans and maize the productivity loss is especially large in Region III, V and VI. For pasture the largest productivity loss is in Region one and VI. Rice, sugar, vegetables and tobacco experience relatively small productivity losses while sorghum, coffee and cotton is in an intermediate position.

To compare these results with results from other erosion studies it is convenient to also estimate average productivity loss per cm soil loss which is shown in table 5.9. Density factors of the soils by production and region are shown in appendix 3.

**Table 5.9. Average annual loss of soil productivity per cm loss of soil by region and crop. 1981-1990. Percent.**

| | Region I | Region II | Region | Region IV | Region V | Region VI |
|---|---|---|---|---|---|---|
| Beans | 1,9 | 1,9 | 2,0 | 1,5 | 2,2 | 1,9 |
| Maize | 2,0 | 1,2 | 1,7 | 1,0 | 1,7 | 1,9 |
| Sorghum | 1,4 | 0,9 | 1,4 | 0,9 | 1,5 | 1,4 |
| Rice | 1,7 | 1,7 | 0,4 | 0,7 | .. | 0,9 |
| Sesame | .. | 1,5 | 1,7 | 1,6 | .. | .. |
| Coffee | 0,7 | 1,3 | 1,0 | 1,1 | 1,5 | 1,3 |
| Cotton | .. | 1,1 | 1,1 | 1,4 | .. | .. |
| Sugar | 0,8 | 0,3 | 0,3 | 0,7 | .. | 0,9 |
| Tobacco | 0,8 | 0,5 | 1,5 | 1,0 | .. | .. |
| Vegetables | 0,3 | .. | .. | .. | .. | 0,9 |
| Pasture | 2,0 | 0,8 | 1,1 | 1,9 | 1,5 | 1,7 |

In table 5.9 the productivity loss is related to the removal of soil measured in depth of soil profile. The productivity loss per cm eroded soil varies between 0,3 and 2,0 percent. The figures are lower for maize than for beans because a larger share of the maize production is located in plain areas where soils are deeper. In Region II and IV, where soils are relatively deep, the figures are lower than in the other regions. For instance the productivity loss per cm eroded soil in sugar, rice, and vegetables seem unreasonably low.

Below we give a general description of the various crops, where they are grown and how exposed they are to erosion.

*Maize and beans*

In the Central Region, except for in the valleys of Jalapa, la Vigia, Pantasma and a few other small valleys, the erosive processes have affected the soils strongly to severely. This is mainly because the cultivation takes place in steep terrains with inclinations up to 50%. The climatic conditions in the central regions are very favourable for the production of maize and beans, but the production capacity is already significantly reduced due to erosion. Maize in the Pacific Region is generally cultivated in areas strongly or very strongly eroded by cotton, but a high level of technology compensates for the effects of soil erosion. In the Pacific Region the most favourable conditions for the production of beans is found in Region IV. Beans are mainly cultivated on land with degree of erosion between low and strong, affecting the yield level correspondingly. However, the productivity is generally low in region IV more due to the unsuitably hot climate than the level of erosion.

*Rice*

In the Central Region the bulk of the production is technified and takes place in Region I in the valley of Jalapa. Here the effect of erosion is moderate. The expansion of rice production into areas of steeper terrains is affecting the soil productivity in rice production due to strong and severe erosion. In the Pacific Region rice grown under irrigation is located in heavy soils on flat land, creating a minimal risk of erosion. However, dry rice on more hilly land with moderate soil textures makes erosion affect the productivity to some extent.

*Coffee*

Coffee is primarily produced in the mountainous areas where the climatic conditions are very favourable. The decline in soil productivity is generally much lower than in the production of annual crops, in spite of the rough topography where the coffee is grown. Coffee is a perennial crop and is usually grown under shade trees, thus giving the soil a protective plant cover. The decline in yields after 1983 is probably due to plagues and diseases and lack of labour because of the war in the years between 1983 and 1989.

*Sorghum*

In the Central Region sorghum is mostly cultivated in small valleys. Here, the problems of drought probably enhanced by erosion is more important for the low productivity than the soil loss per se. In the Pacific Region sorghum is cultivated in the dry zones, and the yields are limited by dry climatic conditions and strongly to severely eroded soils.

*Vegetables*

Production of vegetables is mainly located to flat areas, thereby creating few problems of erosion.

*Cotton*

The disorderly expansion of cotton production during the 1970's had devastating effects on the soils. Extensive areas of flat and rolling land with soils highly susceptible to erosion were improperly managed with regards to adequate soil and water conservation. In region III and IV practically no conservation measures have been applied. Strong and severe erosion has drastically affected yields and soil productivity. On the areas most damaged by erosion, a lot of the cotton production was abandoned during the 1980's and partly replaced by other crops.

*Sesame*

Sesame is primarily grown by small and medium sized producers on soils strongly to severely eroded by cotton. This has considerable effects on the present level of productivity.

*Sugar cane*

Along the Pacific coast, cultivation of sugar cane is generally located to flat areas under irrigation. Thus, erosion rates are low.

*Banana*

Most of the banana is grown for export. Banana is grown on flat land, and the soil is well protected by vegetation and supplies of organic material. Therefore, problems of erosion are insignificant.

*Pasture*

The area used for pasture is about twice as large as the area suitable for cattle. The erosion is high because of overgrazing and compaction. In Region II, the grassland is located on flat areas of heavy soils, which explains why erosion is lower here than in the other regions.

## 6. Integration of environmental variables in economic analyses.

Soil erosion is only one of several environmental problems calling for integration into economic analysis and vice versa. Within the agricultural sphere, the use of chemical fertilizer and pesticides are obvious candidates for integrated studies. Within this project, priority has been given to the soil erosion problem. However, some efforts were also made to investigate the potential for linking the use of agricultural chemicals to economic activity described by a macroeconomic model. Some preliminare results from this work is given in appendix 4.

### 6.1. The soil erosion submodel

The soil erosion submodel uses output levels from 11 agricultural sectors as input for calculating the amount of erosion. The output levels for the agricultural sectors are calculated by an applied general equilibrium model for Nicaragua. In the erosion model, soil loss per hectare is assumed to be constant by crop and region. A change in technology affects the area cultivated for a given level of production. The regional cultivation pattern is assumed to be constant.

In section 5, the average annual rates of soil loss by region and crop over the period 1981-90 were assessed. These provide coefficients for the model determining the yearly amount of soil erosion (tons) by crop and region. It is assumed here that the loss of soil will occur at this rate also for the decade to come. This means that widespread introduction of soil conservation is not supposed to take place in the period. Although some efforts in soil conservation are made, these are not likely to penetrate general agricultural technology for several years. Reasons for this are the institutional and economic barriers to erosion control mentioned in section 2. Consequently, assuming that *what* is grown *where* is the main determinant of erosion rates the next 10 years or so may not be so off target. A description of the erosion sub-model is presented below.

$$Q_i = A_i * B_i * K_i^{1-\alpha_i} L_i^{\alpha_i} \tag{1}$$

$$Q_{ij} = \beta_{ij} Q_i \tag{2}$$

$$H_{ij} = \frac{\mu_{ij}}{A_i B_i} Q_{ij} \tag{3}$$

$$E_{ij} = a_{ij} * H_{ij} \tag{4}$$

$$E_i = \Sigma_j E_{ij} \tag{5}$$

**List of variables:**

$Q_i$ = Production in sector i
$B_i$ = Parameter for erosion-induced productivity loss
$A_i$ = Parameter for factor neutral technical change
$K_i$ = Capital in sector i
$\alpha$ = Cost share of labour in the base year
$L_i$ = Labour in sector i
$Q_{ij}$ = Production in sector i, region j
$\beta_{ij}$ = Parameter for distributing total production in sector i to regional level
$H_{ij}$ = Area of production of crop i, region j (ha)
$\mu_{ij}$ = Parameter for transforming production to area harvested (ha/mill Cordobas)
$E_{ij}$ = Erosion in sector i, region j (tons)
$a_{ij}$ = Rate of erosion for crop i, region j (tons/ha)
$E_i$ = Total erosion in sector i (tons)

Equation (1) is the Cobb-Douglas production function in the general equilibrium model for Nicaragua. Output is being produced by capital and labour. $A_i$ is an exogenous indicator of factor neutral technological change for capital and labour. $B_i$ is the indicator of productivity loss due to erosion. In equation (2), total production in sector i, $Q_i$, is split into regional production levels ($Q_{ij}$), in the same proportions as the regional distribution of production in the base year 1990-91. Equation (3) transforms production into area harvested. The variable for factor neutral technical change and the rate of productivity loss due to erosion enters the equation in order to adjust for the effect of an increase or decrease in productivity. An increase in $A_i$ or $B_i$ in equation (1) implies increased production, and the area necessary to cultivate a certain harvest is reduced. In equation (4) the amount of soil loss for crop i in region j is determined. Equation (5) just sums up the amount of erosion for one crop in all regions.

**7. The Applied General Equilibrium model for Nicaragua.**

The cost of soil erosion is the present value of income foregone and should be subtracted from the conventional income concept. When doing an exercise of estimating foregone earnings due to soil erosion, one should be aware that observed prices are in general not reflecting 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. To measure welfare outside optimum, Mirrlees (1969) pointed at the necessity use shadow prices, that is the prices that govern in optimum where all resources are optimally managed. Aware of this shortcoming, however, we use observed prices in the study of soil erosion in Nicaragua, as also is done in the cost estimates referred to in section 4.

The purpose of our study is somewhat limited compared to a complete soil erosion cost study. Due to lack of data on soil conservation cost, the 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 section contains a brief description of the general equilibrium model for the Nicaraguan economy. The model falls into the neo-classical tradition were it is assumed that consumers maximize utility, producers maximize profit and flexible prices clear markets. Only the labour market is not cleared. Here, the wages are indexed to inflation and not determined by demand and supply. The parameters in the model are calibrated rather than estimated.

According to the model, it is the level of total savings which is the driving force as to generating economic growth. Total savings are invested in production capital, thus to a large extent determining the future production potential. Foreign saving is assumed to be constant, so that domestic saving is the essential variable for economic growth. Savings are proportional to income in four social classes. Since saving rates differ between classes, the income distribution is influencing the accumulation of production capital. The four social classes are campesinos, workers, petty capitalists and capitalists.

Income consists of profit, wages and transfers from abroad. Profit is determined from a sector as the price less indirect taxes and the unit cost multiplied by total production. Total profit is distributed among the four social groups according to fixed coefficients. Total income for workers is wage income + transfers from abroad. Peasants earn a constant share of profit in the agricultural sectors while petty capitalists receive a constant share of profit in urban sectors + transfers from abroad. Total income for capitalists is a fraction of total profit in agricultural sectors + a fraction of profits in the urban sectors + transfers from abroad. Savings equals total income less taxes and total expenditure.

The model has 26 producing sectors that each produces one commodity. The commodities are produced by the input factors labour, capital and intermediates, theintermedates is in fixed proportion to the production level, while there are substitution possibilities 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 is decreasing in the real wage rate. The wage level is indexed to inflation, i.e. the consumer price index for workers.

Total labour supply is growing by a constant rate based on population growth forecasts. 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 sector. Unemployment is determined as labour supply in urban areas less employed in urban areas.

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 supply equals demand.

The capital stock in period t+1 is equal to the capital stock in period t less depreciation + 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.

Domestic 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 non-perfect substitutes (the Armington assumption). The relative prices determine the market shares.

World market prices (in dollars) are exogenous, and the exchange rate is fixed by the government (held constant in this study). The price of imported goods is determined as the world market price (in dollar) multiplied by the exchange rate and adjusted for tariffs on imports. The price of exports is determined as the world market price multiplied by the exchange rate and adjusted for an export subsidy. 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.

Appendix 5 gives a description of the equations in the model and a list of variables.

## 8. Scenario analysis: Impact of soil erosion on economic growth.

In this section we describe the results from simulations on the AGE model for Nicaragua. We focus on the macroeconomic effects of erosion due to productivity losses and estimated amounts of erosion i.e. loss of soil in tons. The scenarios must not be interpreted as actual forecasts of the likely development of the 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 variables.

In the baseline scenario GDP grows at an annual rate of 2,7 percent. As described in section 6.1, soil loss is assumed to be in constant proportions to area harvested by crop and region. Area harvested is proportional to production adjusted for changes in productivity. Over the period 1991-2000 Nicaragua will have lost a total of approximately 970 million tons of soil.

Erosion reduces the productivity of the soil, i.e. yields are reduced for a given level of inputs. In this study we try to quantify the macroeconomic effects of erosion. We do this by introducing a decreasing productivity parameter in the production functions for agricultural products.

The estimates of productivity reductions by crop and region are given in table 5.8. In order to use these results in the model, the regional data were aggregated to national levels by weighing the regional productivity numbers by the region's share of total production of the crop in the base year. Productivity loss by crop on a national level is given in table 8.1.

**Table 8.1. Erosion induced annual productivity loss in agricultural sectors. Percent**

| | |
|---|---|
| Coffee | 1,26 |
| Cotton | 1,31 |
| Bananas | 0,0 |
| Sesame | 2,16 |
| Sugar | 0,13 |
| Maize | 2,41 |
| Beans | 2,52 |
| Rice | 0,33 |
| Sorghum | 1,35 |
| Vegetables | 0,13 |
| Pasture | 2,32 |

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

The loss of productivity will of course reduce output in the agricultural sectors. Reduced output in these sectors will however also affect other sectors in the economy. Since production in the agricultural sectors are reduced, deliveries from other sectors are reduced, shrinking the general production activity. All these effects are incorporated in the input-output core of the model. Table 8.2 shows the main macroeconomic effects of reduced productivity in agriculture due to erosion.

**Table 8.2. Main macroeconomic variables. Deviation from baseline scenario after ten years. Percent.**

| | |
|---|---|
| GDP | -14,5 |
| Imports | -11,3 |
| Exports | -14,5 |
| Private consumption | -13,7 |
| Investment | -23,7 |

The table shows that production, imports, exports and consumption are reduced by 11-14 percent compared to the baseline scenario, while investment is reduced by almost 24 percent.

The reduction in investment is much larger than the reduction in the other variables and requires some further explanation.

Total investment is determined by total savings which consists of savings by households, government and foreign savings. Foreign savings is exogenous while savings by households is determined as a constant share of household income. Government savings is determined by equating total government revenue by total government expenditure. When production is reduced, government income is reduced due to lower revenue from indirect taxes and income taxes. Government expenditure on goods is, however, exogenous in the model, so government savings must therefore be reduced in order to balance the budget revenue with government expenditure. The reduction in household and government saving together implies a reduction in savings of almost 24 percent and consequently a corresponding reduction in investment. A relative big income reduction for capitalist and small urban proprietos contributes to lower household savings, as workers and and campesinos save less in comparison.

Table 8.3 shows the effects on output, labour and prices in the various sectors of the economy.

**Table 8.3. Output, labour, wages and prices. Deviation from baseline after ten years. Percent.**

| | Output | Labour | Wages | Prices |
|---|---|---|---|---|
| Coffee | -18,5 | -32,4 | 20,0 | 0,3 |
| Cotton | -21,2 | -34,8 | 20,0 | 0,1 |
| Bananas | -4,7 | -21,3 | 20,2 | -0,2 |
| Sesame | -27,9 | -40,0 | 20,2 | 0,7 |
| Sugar | -12,2 | -21,6 | 19,9 | 5,0 |
| Maize | -22,2 | -16,2 | 19,9 | 17,2 |
| Beans | -22,8 | -6,7 | 19,9 | 19,1 |
| Rice | -8,1 | -36,2 | 19,8 | -1,6 |
| Sorghum | -18,5 | -77,2 | 19,9 | -31,9 |
| Other agriculture | -4,7 | -25,5 | 20,0 | -0,7 |
| Cattle | -21,0 | 7,5 | 20,0 | 16,8 |
| Forestry | -5,0 | -31,4 | 20,0 | -6,3 |
| Fishery | -6,4 | -34,1 | 20,1 | -0,2 |
| Mining | -5,2 | -22,3 | 20,1 | -0,4 |
| Food and beverages | -12,2 | -30,7 | 20,0 | 1,0 |
| Textiles | -19,6 | -36,7 | 20,0 | 0,1 |
| Chemicals | -12,7 | -31,1 | 20,0 | 0,1 |
| Oil production | -12,0 | -56,5 | 20,0 | 0,1 |
| Other industries | -11,7 | -33,3 | 20,0 | -0,4 |
| Electricity | -34,2 | -37,7 | 20,0 | 5,4 |
| Water | -10,8 | -20,1 | 20,0 | 6,8 |
| Construction | -21,2 | -35,0 | 20,0 | 0,6 |
| Services | -16,9 | -22,4 | 20,0 | 8,6 |
| Transport and comm. | -12,8 | -27,7 | 20,0 | -0,1 |
| Education and health | -4,0 | -4,3 | 20,0 | 16,2 |
| Trade | -13,8 | -27,1 | 20,0 | 1,6 |
| Total | -14,6 | -25,0 | | |

*Production*

Falling soil productivity reduces production in the agricultural sectors directly and indirectly. As table 8.3 shows, it is sesame, beans and maize that experience the largest reductions, because it is these sectors that experience the largest productivity losses due to erosion. Reduced production in the agricultural sectors does also affect production in non-agricultural sectors. The reduction in production in agricultural sectors implies that these sectors need less intermediate goods from other sectors, which in turn leads to reduced production in these sectors. The reduction in production in non-agricultural sectors is largest for electricity.

*Demand for labour*

Total demand for labour is reduced by 25 percent. Production shifts downwords in all sectors, and lower activity shrinks labour demand. However, the labour demand is also affected by the change in sales price, the cost of other input factors like capital intermediates, and of course by the wage rate itself. Wages are indexed to the general price level which is rising, thus wages also increase and make producers demand less labour. The wage rate increases by approximately 20 percent in all sectors. Declining production and rising wages consequently both tend to undermine unemployment opprtunities. On the other hand the price effects are ambigous. For 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 this production.

Among the non-agricultural sectors it is the refinery sector that experiences the largest reduction in employment. The main reason for this is a relatively large reduction in the net-price. Demand for labour in production of sorghum is reduced by 77 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.

The drastic reduction in labour demand should be judged on 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 that such a wage formation could sustain. 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.

*Prices*

The prices in the model adjust 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 8.3 shows that some prices are reduced and some are increased. The increase in prices is largest for maize, beans and pasture for the agricultural sectors and education and health among the non-agricultural sectors. Sorghum experiences the largest reduction in prices. The large increase in the price of maize and beans and a modest reduction in production indicates that the demand for basic food grains is rather inelastic. As a consequence a part of the cost of erosion is passed on to other social classes than campesinos. In table 8.4 the effect on income for the four social classes is shown.

This result illustrates a theoretical aspect concerning the valuation of natural resource depletion in an open economy 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, partly compensating the reduction in resource capital assets. 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 notice their improved terms of trade with the rest of the economy.

**Table 8.4. Effect on income distribution. Percent deviation from baseline after ten years.**

| | Income |
|---|---|
| Campesinos | -9,4 |
| Urban workers | -12,9 |
| Urban small proprietors | -16,8 |
| Capitalists | -15,7 |
| Total | -14,0 |

Although the total income is reduced more for other classes than the campesinos, the impact on income levels per capita might be more even due to the impact of migration. In the model, rural-urban migration is determined by the last years relation between income growth in the two parts of the economy. The erosion cost makes income grow less rapid in the urban sector than in rural sector. Thus migration to the urban sector is dampened, leaving a bigger share of the population dependant on the income generated by the rural economy.

## 9. Conclusions

Most erosion studies focus on small local areas and do not try to assess the effects of erosion on agents outside that area. To better assess the total economic implications we believe it is necessary to have a national perspective on soil erosion. In this report we analyse the macroeconomic effects of erosion induced reduction in agricultural productivity in Nicaragua. We do this by using a multisectoral macroeconomic model for the Nicaraguan economy. Through modelling of the interrelationship between sectors, we see how reduced productivity in the agricultural sectors influences activity and prices in other sectors. We find that after a period of ten years gross domestic product (GDP) and private consumption are reduced by 14 and 13 percent respectively compared to a baseline scenario without productivity loss. Investment is reduced by almost 24 percent. Sesame, beans and maize experience the largest reductions in production. Production in non-agricultural sectors is reduced because rising food prices and wage level increases the general domestic cost level. Demand for labour in the formal sector decreases by 25 percent.

At this stage, the focus has been on establishing the model framework, rather than creating a realistic policy scenario. Hence, the results are only illustrative. When doing this study we admittedly take many shortcuts in our estimates of soil loss and yield decline. Thus, the numbers that we report are uncertain and should be interpreted with caution. However, we still see the approach with linking environmental problems to macroeconomic models as useful. It shows that soil degradation matters to the whole economy, also to non-agricultural sectors. Hopefully the quantification of these impacts may serve as an eye-opener to decision makers who usually see soil erosion as outside their field. It is also our hope that a formal study at the macro level such as the present one can stimulate cooperation between soil scientists and economists in order to produce better data and better modelling of the links between soil erosion and economic development.

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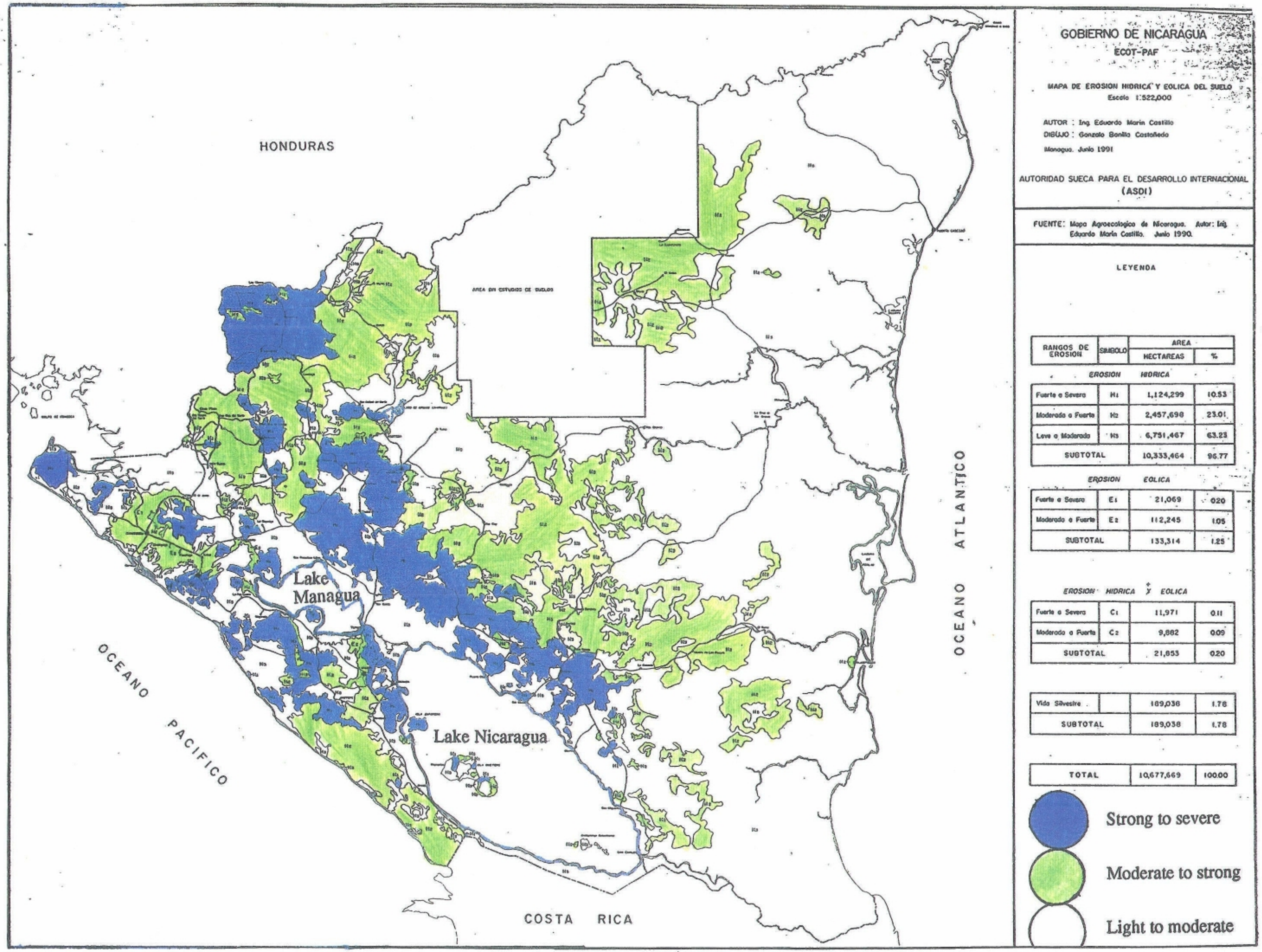


Appendix 1. Erosion Map.

# Appendix 2. Annual yield by crop and region 1966-1991.

## Region I

| Crop | | 1965-66 | 1970-71 | 1975-76 | 1976-77 | 1977-78 | 1978-79 | 1979-80 | 1980-81 | 1981-82 | 1982-83 | 1983-84 | 1984-85 | 1986-87 | 1987-88 | 1988-89 | 1989-90 | 1990-91 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Beans** | Area (mzs.) | 7507 | 12397 | 23331 | 23201 | 19997 | 43310 | 17861 | 14595 | 23792 | 24623 | 29237 | 24500 | 32000 | 20200 | 35629 | 30707 | 32033 |
| | Prod. (qq) | 77952 | 146141 | 167168 | 202047 | 166252 | 517312 | 144434 | 157969 | 266873 | 249862 | 351665 | 256900 | 337800 | 160700 | 279300 | 263500 | 328500 |
| | Yield (qq/mz) | 10,4 | 11,8 | 7,2 | 8,7 | 8,3 | 11,9 | 8,1 | 10,8 | 11,2 | 10,1 | 12,0 | 10,5 | 10,6 | 8,0 | 7,8 | 8,6 | 10,3 |
| **Maize** | Area (mzs.) | 25946 | 27122 | 27444 | 35153 | 35288 | 59631 | 38300 | 11450 | 38806 | 25349 | 28855 | 30200 | 32300 | 36500 | 43000 | 33782 | 20897 |
| | Prod. (qq) | 287012 | 337597 | 347043 | 347553 | 438754 | 897519 | 492838 | 215824 | 614021 | 390215 | 551471 | 804300 | 1100000 | 1330000 | 1384900 | 1421300 | 758600 |
| | Yield (qq/mz) | 11,1 | 12,4 | 12,6 | 9,9 | 12,4 | 15,1 | 12,9 | 18,8 | 15,8 | 15,4 | 19,1 | 26,6 | 34,1 | 36,4 | 32,2 | 42,1 | 36,3 |
| **Sorghum** | Area (mzs.) | 7777 | 10181 | 15568 | 12682 | 3585 | 9776 | 4991 | 4220 | 6640 | 5668 | 5238 | 5400 | 5100 | 2900 | 4210 | 7212 | 11025 |
| | Prod. (qq) | 105924 | 139295 | 218368 | 136119 | 45806 | 148156 | 72130 | 57186 | 98043 | 63693 | 117133 | 117300 | 115900 | 38800 | 106400 | 146000 | 204000 |
| | Yield (qq/mz) | 13,6 | 13,7 | 14,0 | 10,7 | 12,8 | 15,2 | 14,5 | 13,6 | 14,8 | 11,2 | 22,4 | 21,7 | 22,7 | 13,4 | 25,3 | 20,2 | 18,5 |
| **Rice** | Area (mzs.) | 439 | 441 | 1631 | 184 | 1136 | 2381 | 2496 | 1777 | 1095 | 5251 | 3675 | 4400 | 1700 | 3200 | 2980 | 3380 | 2473 |
| | Prod. (qq) | 9447 | 7128 | 42637 | 7794 | 52080 | 64040 | 42361 | 57330 | 29575 | 168900 | 131983 | 157300 | 72000 | 102100 | 111000 | 114170 | 78991 |
| | Yield (qq/mz) | 21,5 | 16,2 | 26,1 | 42,4 | 45,8 | 26,9 | 17,0 | 32,3 | 27,0 | 32,2 | 35,9 | 35,8 | 42,4 | 31,9 | 37,2 | 33,8 | 31,9 |
| **Sesame** | Area (mzs.) | 574 | 187 | 178 | 185 | 461 | 502 | .. | 419 | 93 | 85 | 84 | 200 | .. | .. | .. | .. | 110 |
| | Prod. (qq) | 4990 | 1492 | 1600 | 1500 | 4205 | 4208 | .. | 2631 | 569 | 621 | 618 | 2000 | .. | .. | .. | .. | 1230 |
| | Yield (qq/mz) | 8,7 | 8,0 | 9,0 | 8,1 | 9,1 | 8,4 | .. | 6,3 | 6,1 | 7,3 | 7,4 | 10,0 | .. | .. | .. | .. | 11,2 |
| **Coffee** | Area (mzs.) | 20989 | 23424 | 31948 | 27151 | 27578 | 27907 | 25000 | 25000 | 24635 | 25027 | 25027 | 20324 | 17948 | 18771 | 20951 | 21378 | 24759 |
| | Prod. (qq) | 89042 | 100859 | 107344 | 128954 | 146269 | 147652 | 136202 | 227998 | 236725 | 271696 | 189558 | 121700 | 132200 | 119533 | 149074 | 181671 | 138819 |
| | Yield (qq/mz) | 4,2 | 4,3 | 3,4 | 4,7 | 5,3 | 5,3 | 5,4 | 9,1 | 9,6 | 10,9 | 7,6 | 6,0 | 7,4 | 6,4 | 7,1 | 8,5 | 5,6 |
| **Cotton** | Area (mzs.) | 3472 | 46 | .. | 13 | 53 | 20 | .. | 122 | 263 | 239 | 138 | 49 | .. | .. | .. | .. | .. |
| | Prod. (qq) | 89166 | 552 | .. | 196 | 1325 | 660 | .. | 4985 | 7890 | 6606 | 2795 | 1720 | .. | .. | .. | .. | .. |
| | Yield (qq/mz) | 25,7 | 12,0 | .. | 15,1 | 25,0 | 33,0 | .. | 40,9 | 30,0 | 27,6 | 20,3 | 35,1 | .. | .. | .. | .. | .. |
| **Sugar** | Area (mzs.) | 2318 | 828 | 855 | 1237 | 1251 | 212 | 197 | 817 | 912 | 912 | 912 | .. | .. | .. | .. | .. | .. |
| | Prod. (qq) | 47966 | 17480 | 21520 | 23317 | 23785 | 2947 | 2365 | 14703 | 16826 | 27344 | 27344 | .. | .. | .. | .. | .. | .. |
| | Yield (qq/mz) | 20,7 | 21,1 | 25,2 | 18,8 | 19,0 | 13,9 | 12,0 | 18,0 | 18,4 | 30,0 | 30,0 | .. | .. | .. | .. | .. | .. |
| **Tobacco** | Area (mzs.) | .. | .. | .. | .. | .. | .. | .. | 694 | 689 | 502 | 1255 | 1100 | .. | .. | .. | .. | .. |
| | Prod. (qq) | .. | .. | .. | .. | .. | .. | .. | 21664 | 22152 | 18128 | 40821 | 23900 | .. | .. | .. | .. | .. |
| | Yield (qq/mz) | .. | .. | .. | .. | .. | .. | .. | 31,2 | 32,2 | 36,1 | 32,5 | 21,7 | .. | .. | .. | .. | .. |

## Region II

| | | 1965-66 | 1970-71 | 1975-76 | 1976-77 | 1977-78 | 1978-79 | 1979-80 | 1980-81 | 1981-82 | 1982-83 | 1983-84 | 1984-85 | 1986-87 | 1987-88 | 1988-89 | 1989-90 | 1990-91 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Beans** | Area (mzs.) | 1612 | 1717 | 2450 | 3732 | 812 | 2726 | 691 | 1470 | 4444 | 9151 | 5160 | 3300 | 6345 | 6558 | 8158 | 10197 | 9666 |
| | Prod. (qq) | 18301 | 18412 | 15880 | 29349 | 6628 | 29605 | 4949 | 11520 | 34115 | 149450 | 63065 | 29300 | 51000 | 42242 | 56200 | 48400 | 58500 |
| | Yield (qq/mz) | 11,4 | 10,7 | 6,5 | 7,9 | 8,2 | 10,9 | 7,2 | 7,8 | 7,7 | 16,3 | 12,2 | 8,9 | 8,0 | 6,4 | 6,9 | 4,7 | 6,1 |
| **Maize** | Area (mzs.) | 32439 | 46710 | 39045 | 35421 | 68278 | 52621 | 59093 | 49734 | 47603 | 16989 | 21082 | 23700 | 15230 | 36690 | 49351 | 27441 | 19456 |
| | Prod. (qq) | 489321 | 646045 | 482769 | 509200 | 830129 | 994493 | 734493 | 815562 | 1044446 | 614588 | 669701 | 910600 | 267200 | 1186874 | 1043200 | 694900 | 283800 |
| | Yield (qq/mz) | 15,1 | 13,8 | 12,4 | 14,4 | 12,2 | 18,9 | 12,4 | 16,4 | 21,9 | 36,2 | 31,8 | 38,4 | 17,5 | 32,3 | 21,1 | 25,3 | 14,6 |
| **Sorghum** | Area (mzs.) | 9490 | 21998 | 10555 | 9789 | 35327 | 29192 | 14298 | 6175 | 36713 | 15240 | 14804 | 16400 | 43373 | 44998 | 42487 | 26795 | 22622 |
| | Prod. (qq) | 134684 | 356660 | 161437 | 193646 | 518133 | 648951 | 401148 | 148969 | 843828 | 292905 | 380128 | 440500 | 1327500 | 885519 | 1018100 | 416600 | 345400 |
| | Yield (qq/mz) | 14,2 | 16,2 | 15,3 | 19,8 | 14,7 | 22,2 | 28,1 | 24,1 | 23,0 | 19,2 | 25,7 | 26,9 | 30,6 | 19,7 | 24,0 | 15,5 | 15,3 |
| **Rice** | Area (mzs.) | 2305 | 2400 | 4190 | 2253 | 3406 | 650 | 196 | 2449 | 16223 | 10497 | 9318 | 5700 | 10300 | 11200 | 18180 | 17670 | 11902 |
| | Prod. (qq) | 48357 | 63170 | 128291 | 85540 | 140040 | 21746 | 2940 | 81460 | 482797 | 296300 | 319977 | 206300 | 305100 | 306500 | 471800 | 358570 | 316726 |
| | Yield (qq/mz) | 21,0 | 26,3 | 30,6 | 38,0 | 41,1 | 33,5 | 15,0 | 33,3 | 29,8 | 28,2 | 34,3 | 36,2 | 29,6 | 27,4 | 26,0 | 20,3 | 26,6 |
| **Sesame** | Area (mzs.) | 5088 | 9601 | 5520 | 4619 | 7324 | 6205 | 9088 | 21965 | 17618 | 9706 | 17545 | 17700 | 8751 | 8233 | 12169 | 30499 | 39447 |
| | Prod. (qq) | 60594 | 94907 | 51579 | 42845 | 71533 | 62988 | 83551 | 142992 | 117340 | 70807 | 201620 | 120300 | 68923 | 54370 | 62003 | 166761 | 183933 |
| | Yield (qq/mz) | 11,9 | 9,9 | 9,3 | 9,3 | 9,8 | 10,2 | 9,2 | 6,5 | 6,7 | 7,3 | 11,5 | 6,8 | 7,9 | 6,6 | 5,1 | 5,5 | 4,7 |
| **Coffee** | Area (mzs.) | 1090 | 1202 | 1306 | 780 | 780 | 784 | 1200 | 1200 | 1593 | 1593 | 1593 | 1435 | 1412 | 1400 | 800 | 830 | 758 |
| | Prod. (qq) | 5792 | 6170 | 4693 | 3826 | 4254 | 4295 | 4667 | 7936 | 8362 | 6127 | 4182 | 7500 | 4000 | 4900 | 4706 | 10056 | 5944 |
| | Yield (qq/mz) | 5,3 | 5,1 | 3,6 | 4,9 | 5,5 | 5,5 | 3,9 | 6,6 | 5,2 | 3,8 | 2,6 | 5,2 | 2,8 | 3,5 | 5,9 | 12,1 | 7,8 |
| **Cotton** | Area (mzs.) | 146103 | 111793 | 181413 | 238052 | 256115 | 211061 | 48818 | 119340 | 117931 | 113346 | 145242 | 142700 | 78856 | 82500 | 56780 | 47510 | 61052 |
| | Prod. (qq) | 5008982 | 4410177 | 6481323 | 6978864 | 7889222 | 6876855 | 981193 | 4357830 | 3539743 | 4468907 | 4937335 | 4004200 | 3122986 | 2139800 | 1553730 | 1400850 | 1758010 |
| | Yield (qq/mz) | 34,3 | 39,4 | 35,7 | 29,3 | 30,8 | 32,6 | 20,1 | 36,5 | 30,0 | 39,4 | 34,0 | 28,1 | 39,6 | 25,9 | 27,4 | 29,5 | 28,8 |
| **Sugar** | Area (mzs.) | 15497 | 27849 | 36181 | 29822 | 30206 | 34223 | 32003 | 34489 | 38501 | 35981 | 34654 | 35880 | 32605 | 32877 | 26205 | 31512 | 31303 |
| | Prod. (qq) | 669872 | 1371767 | 1783425 | 1777432 | 1822459 | 1953909 | 1549972 | 1819651 | 2121608 | 1791323 | 1907189 | 1518700 | 1482521 | 1289191 | 993184 | 1358084 | 1491725 |
| | Yield (qq/mz) | 43,2 | 49,3 | 49,3 | 59,6 | 60,3 | 57,1 | 48,4 | 52,8 | 55,1 | 49,8 | 55,0 | 42,3 | 45,5 | 39,2 | 37,9 | 43,1 | 47,7 |
| **Tobacco** | Area (mzs.) | .. | .. | .. | .. | .. | .. | .. | 35 | .. | .. | 307 | 300 | .. | .. | .. | .. | .. |
| | Prod. (qq) | .. | .. | .. | .. | .. | .. | .. | 551 | .. | .. | 5954 | 4300 | .. | .. | .. | .. | .. |
| | Yield (qq/mz) | .. | .. | .. | .. | .. | .. | .. | 15,7 | .. | .. | 19,4 | 14,3 | .. | .. | .. | .. | .. |
| **Banano** | | 1965 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 |
| | Area (mzs.) | 625 | 3292 | 3464 | 3410 | 3728 | 4052 | 3726 | 3780 | 3214 | 3800 | 3200 | 3800 | 3800 | 3500 | 3200 | 3800 | 3500 |
| | Prod.(boxes) | 431177 | 6802042 | 6097637 | 6074978 | 6522106 | 6501150 | 6308620 | 4478429 | 6895004 | 6051400 | 6895000 | 6051400 | 5950800 | 5665600 | 4999000 | 5400400 | 5681300 |
| | Yield (box/mz) | 689,9 | 2066,2 | 1760,3 | 1781,5 | 1749,5 | 1604,4 | 1693,1 | 1184,8 | 2145,3 | 1592,5 | 2154,7 | 1592,5 | 1566,0 | 1618,7 | 1562,2 | 1421,2 | 1623,2 |

# Region III

| | | 1965-66 | 1970-71 | 1975-76 | 1976-77 | 1977-78 | 1978-79 | 1979-80 | 1980-81 | 1981-82 | 1982-83 | 1983-84 | 1984-85 | 1986-87 | 1987-88 | 1988-89 | 1989-90 | 1990-91 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Beans** | Area (mzs.) | 2630 | 1258 | 2156 | 4044 | 1112 | 6157 | 2568 | 946 | 2474 | 1396 | 1193 | 1800 | 4703 | 4225 | 5023 | 3058 | 2596 |
| | Prod. (qq) | 26512 | 11507 | 9335 | 25723 | 7673 | 54172 | 14000 | 4100 | 14578 | 14560 | 10730 | 18000 | 41100 | 23256 | 23400 | 24900 | 19100 |
| | Yield (qq/mz) | 10,1 | 9,1 | 4,3 | 6,4 | 6,9 | 8,8 | 5,5 | 4,3 | 5,9 | 10,4 | 9,0 | 10,0 | 8,7 | 5,5 | 4,7 | 8,1 | 7,4 |
| **Maize** | Area (mzs.) | 15079 | 10270 | 10184 | 12300 | 5075 | 16336 | 7880 | 5042 | 6423 | 5943 | 5687 | 5300 | 10747 | 6453 | 7636 | 3796 | 4110 |
| | Prod. (qq) | 191808 | 169390 | 99393 | 147713 | 48705 | 243702 | 107520 | 31243 | 62846 | 144705 | 141188 | 259300 | 346900 | 181663 | 185700 | 112600 | 97600 |
| | Yield (qq/mz) | 12,7 | 16,5 | 9,8 | 12,0 | 9,6 | 14,9 | 13,6 | 6,2 | 9,8 | 24,3 | 24,8 | 48,9 | 32,3 | 28,2 | 24,3 | 29,7 | 23,7 |
| **Sorghum** | Area (mzs.) | 5713 | 6933 | 23698 | 33884 | 5955 | 8495 | 8373 | 22950 | 15352 | 7682 | 15241 | 21900 | 25674 | 23937 | 14418 | 5301 | 5501 |
| | Prod. (qq) | 91358 | 101983 | 383146 | 986998 | 86431 | 164465 | 155382 | 841802 | 406828 | 155769 | 601638 | 829900 | 759100 | 435627 | 408500 | 138100 | 169200 |
| | Yield (qq/mz) | 16,0 | 14,7 | 16,2 | 29,1 | 14,5 | 19,4 | 18,6 | 36,7 | 26,5 | 20,3 | 39,5 | 37,9 | 29,6 | 18,2 | 28,3 | 26,1 | 30,8 |
| **Rice** | Area (mzs.) | 2327 | 3631 | 6215 | 3869 | 1641 | 2277 | 605 | 5738 | 3505 | 2209 | 2915 | 4500 | 300 | 100 | 610 | 750 | 151 |
| | Prod. (qq) | 42894 | 124475 | 203539 | 124873 | 36621 | 85038 | 21713 | 211635 | 144561 | 97100 | 143234 | 196800 | 5800 | 2000 | 16300 | 15000 | 1469 |
| | Yield (qq/mz) | 18,4 | 34,3 | 32,7 | 32,3 | 22,3 | 37,3 | 35,9 | 36,9 | 41,2 | 44,0 | 49,1 | 43,7 | 19,3 | 20,0 | 26,7 | 20,0 | 9,7 |
| **Sesame** | Area (mzs.) | 2560 | 403 | 824 | 276 | 449 | 1267 | 282 | 1896 | 1449 | 1802 | 1836 | 1300 | 544 | 1039 | 267 | 4420 | 5839 |
| | Prod. (qq) | 24269 | 4999 | 6875 | 2722 | 4423 | 12365 | 2180 | 14128 | 11629 | 17189 | 17229 | 13000 | 4911 | 3143 | 2681 | 34904 | 48435 |
| | Yield (qq/mz) | 9,5 | 12,4 | 8,3 | 9,9 | 9,9 | 9,8 | 7,7 | 7,5 | 8,0 | 9,5 | 9,4 | 10,0 | 9,0 | 3,0 | 10,0 | 7,9 | 8,3 |
| **Coffee** | Area (mzs.) | 16925 | 24537 | 34898 | 20775 | 20780 | 21038 | 20000 | 20000 | 15519 | 15435 | 15435 | 15524 | 9359 | 9956 | 7810 | 7477 | 7477 |
| | Prod. (qq) | 94137 | 150903 | 185219 | 149831 | 170042 | 171651 | 186187 | 115217 | 113557 | 141656 | 71291 | 48800 | 36200 | 58068 | 34884 | 58744 | 24650 |
| | Yield (qq/mz) | 5,6 | 6,2 | 5,3 | 7,2 | 8,2 | 8,2 | 9,3 | 5,8 | 7,3 | 9,2 | 4,6 | 3,1 | 3,9 | 5,8 | 4,5 | 7,9 | 3,3 |
| **Cotton** | Area (mzs.) | 28975 | 13015 | 13970 | 26406 | 29917 | 18441 | 3927 | 4300 | 3750 | 6129 | 7908 | 9390 | 2372 | 500 | .. | .. | .. |
| | Prod. (qq) | 1098534 | 415032 | 467576 | 551357 | 589266 | 598795 | 62403 | 140349 | 132472 | 202617 | 227593 | 240766 | 71427 | 10600 | .. | .. | .. |
| | Yield (qq/mz) | 37,9 | 31,9 | 33,5 | 20,9 | 19,7 | 32,5 | 15,9 | 32,6 | 35,3 | 33,1 | 28,8 | 25,6 | 30,1 | 21,2 | .. | .. | .. |
| **Sugar** | Area (mzs.) | 5657 | 6672 | 8076 | 6953 | 7041 | 6553 | 6132 | 6534 | 7294 | 8796 | 8346 | 7700 | 11499 | 11407 | 10655 | 13472 | 16180 |
| | Prod. (qq) | 238216 | 274099 | 387390 | 244142 | 250431 | 330384 | 262190 | 288883 | 336827 | 373564 | 355034 | 372600 | 489486 | 468015 | 510738 | 557058 | 772719 |
| | Yield (qq/mz) | 42,1 | 41,1 | 48,0 | 35,1 | 35,6 | 50,4 | 42,8 | 44,2 | 46,2 | 42,5 | 42,5 | 48,4 | 42,6 | 41,0 | 47,9 | 41,3 | 47,8 |
| **Tobacco** | Area (mzs.) | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 171 | 200 | .. | .. | .. | .. | .. |
| | Prod. (qq) | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 4037 | 2800 | .. | .. | .. | .. | .. |
| | Yield (qq/mz) | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 23,6 | 14,0 | .. | .. | .. | .. | .. |

## Region IV

| | | 1965-66 | 1970-71 | 1975-76 | 1976-77 | 1977-78 | 1978-79 | 1979-80 | 1980-81 | 1981-82 | 1982-83 | 1983-84 | 1984-85 | 1986-87 | 1987-88 | 1988-89 | 1989-90 | 1990-91 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Beans** | Area (mzs.) | 9861 | 6855 | 12095 | 17577 | 14783 | 26761 | 11536 | 10766 | 16459 | 8471 | 16668 | 13700 | 25563 | 18502 | 16324 | 18320 | 18561 |
| | Prod. (qq) | 111444 | 73646 | 67753 | 131868 | 127512 | 277362 | 74440 | 65591 | 130615 | 92229 | 186784 | 150300 | 223300 | 103700 | 104000 | 158200 | 162400 |
| | Yield (qq/mz) | 11,3 | 10,7 | 5,6 | 7,5 | 8,6 | 10,4 | 6,5 | 6,1 | 7,9 | 10,9 | 11,2 | 11,0 | 8,7 | 5,6 | 6,4 | 8,6 | 8,7 |
| **Maize** | Area (mzs.) | 28392 | 24313 | 25984 | 25539 | 35290 | 41681 | 27715 | 28389 | 36688 | 11046 | 16502 | 13900 | 25860 | 20241 | 29124 | 14891 | 21336 |
| | Prod. (qq) | 389568 | 433716 | 410938 | 433219 | 434362 | 817100 | 424780 | 732915 | 513013 | 183339 | 596689 | 518500 | 877900 | 894000 | 1113600 | 492600 | 642000 |
| | Yield (qq/mz) | 13,7 | 17,8 | 15,8 | 17,0 | 12,3 | 19,6 | 15,3 | 25,8 | 14,0 | 16,6 | 36,2 | 37,3 | 33,9 | 44,2 | 38,2 | 33,1 | 30,1 |
| **Sorghum** | Area (mzs.) | 7118 | 4618 | 7320 | 19359 | 8063 | 12380 | 23994 | 20707 | 14835 | 18168 | 25543 | 19800 | 26675 | 27217 | 18941 | 19911 | 18562 |
| | Prod. (qq) | 98978 | 78628 | 104506 | 667957 | 141909 | 216598 | 443768 | 662080 | 431796 | 498039 | 949209 | 756600 | 1051800 | 831800 | 557800 | 734800 | 727700 |
| | Yield (qq/mz) | 13,9 | 17,0 | 14,3 | 34,5 | 17,6 | 17,5 | 18,5 | 32,0 | 29,1 | 27,4 | 37,2 | 38,2 | 39,4 | 30,6 | 29,4 | 36,9 | 39,2 |
| **Rice** | Area (mzs.) | 10112 | 10996 | 8771 | 5290 | 3128 | 10748 | 24143 | 9286 | 21035 | 18031 | 17478 | 11500 | 13400 | 11400 | 8490 | 9510 | 12744 |
| | Prod. (qq) | 215692 | 243577 | 258230 | 129907 | 78166 | 313176 | 668681 | 277813 | 691877 | 634771 | 552370 | 438600 | 411000 | 332300 | 202700 | 235440 | 369249 |
| | Yield (qq/mz) | 21,3 | 22,2 | 29,4 | 24,6 | 25,0 | 29,1 | 27,7 | 29,9 | 32,9 | 35,2 | 31,6 | 38,1 | 30,7 | 29,1 | 23,9 | 24,8 | 29,0 |
| **Sesame** | Area (mzs.) | 3950 | 3247 | 2708 | 2771 | 3844 | 5665 | 2034 | 4614 | 2190 | 2286 | 2535 | 2800 | 1473 | 1086 | 1321 | 3654 | 5068 |
| | Prod. (qq) | 42873 | 37444 | 25322 | 31211 | 38069 | 63404 | 21975 | 31545 | 18178 | 21845 | 30533 | 31900 | 12600 | 10209 | 7265 | 22609 | 43300 |
| | Yield (qq/mz) | 10,9 | 11,5 | 9,4 | 11,3 | 9,9 | 11,2 | 10,8 | 6,8 | 8,3 | 9,6 | 12,0 | 11,4 | 8,6 | 9,4 | 5,5 | 6,2 | 8,5 |
| **Coffee** | Area (mzs.) | 24697 | 34228 | 65397 | 38924 | 38934 | 39434 | 29800 | 21014 | 19188 | 18415 | 20615 | 20630 | 17934 | 15548 | 16280 | 15203 | 13627 |
| | Prod. (qq) | 156871 | 181409 | 269231 | 217763 | 247743 | 249581 | 267123 | 146965 | 133235 | 214402 | 86231 | 164600 | 123000 | 135000 | 116578 | 221264 | 57730 |
| | Yield (qq/mz) | 6,4 | 5,3 | 4,1 | 5,6 | 6,4 | 6,3 | 9,0 | 7,0 | 6,9 | 11,6 | 4,2 | 8,0 | 6,9 | 8,7 | 7,2 | 14,6 | 4,2 |
| **Cotton** | Area (mzs.) | 19431 | 8952 | 9218 | 16744 | 21925 | 17839 | 11288 | 10789 | 10779 | 9437 | 14273 | 12161 | 3552 | 1900 | 770 | 2042 | 2040 |
| | Prod. (qq) | 748906 | 291637 | 333934 | 583287 | 609410 | 651686 | 301094 | 374247 | 400894 | 392006 | 532016 | 361959 | 94624 | 49600 | 7670 | 31760 | 29388 |
| | Yield (qq/mz) | 38,5 | 32,6 | 36,2 | 34,8 | 27,8 | 36,5 | 26,7 | 34,7 | 37,2 | 41,5 | 37,3 | 29,8 | 26,6 | 26,1 | 10,0 | 15,6 | 14,4 |
| **Sugar** | Area (mzs.) | 5349 | 5732 | 8842 | 11086 | 11230 | 12645 | 11834 | 10963 | 12241 | 14866 | 13743 | 12600 | 12472 | 2200 | 8703 | 10053 | 10443 |
| | Prod. (qq) | 187258 | 210148 | 480724 | 445067 | 456297 | 594154 | 471422 | 439758 | 512875 | 642611 | 697064 | 549200 | 508113 | 66000 | 384913 | 441210 | 447071 |
| | Yield (qq/mz) | 35,0 | 36,7 | 54,4 | 40,1 | 40,6 | 47,0 | 39,8 | 40,1 | 41,9 | 43,2 | 50,7 | 43,6 | 40,7 | 30,0 | 44,2 | 43,9 | 42,8 |
| **Tobacco** | Area (mzs.) | .. | .. | .. | .. | .. | .. | .. | 688 | 350 | 320 | 681 | 600 | .. | .. | .. | .. | .. |
| | Prod. (qq) | .. | .. | .. | .. | .. | .. | .. | 17475 | 11799 | 9421 | 17301 | 16400 | .. | .. | .. | .. | .. |
| | Yield (qq/mz) | .. | .. | .. | .. | .. | .. | .. | 25,4 | 33,7 | 29,4 | 25,4 | 27,3 | .. | .. | .. | .. | .. |

# Region V

| | | 1965-66 | 1970-71 | 1975-76 | 1976-77 | 1977-78 | 1978-79 | 1979-80 | 1980-81 | 1981-82 | 1982-83 | 1983-84 | 1984-85 | 1986-87 | 1987-88 | 1988-89 | 1989-90 | 1990-91 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Beans** | Area (mzs.) | 7449 | 8422 | 4549 | 10360 | 5169 | 11244 | 4127 | 4388 | 4325 | 23932 | 33870 | 34100 | 25030 | 15100 | 28834 | 35226 | 38094 |
| | Prod. (qq) | 88804 | 89679 | 24734 | 96687 | 38570 | 144940 | 24654 | 29668 | 22769 | 200539 | 259267 | 338000 | 195700 | 124900 | 277600 | 315400 | 337300 |
| | Yield (qq/mz) | 11,9 | 10,6 | 5,4 | 9,3 | 7,5 | 12,9 | 6,0 | 6,8 | 5,3 | 8,4 | 7,7 | 9,9 | 7,8 | 8,3 | 9,6 | 9,0 | 8,9 |
| **Maize** | Area (mzs.) | 59357 | 69607 | 24669 | 42582 | 24476 | 56240 | 21460 | 35025 | 36827 | 95352 | 104559 | 97600 | 42900 | 57900 | 68457 | 112288 | 95491 |
| | Prod. (qq) | 775984 | 745708 | 261012 | 522270 | 254638 | 909511 | 228379 | 683294 | 310240 | 1315062 | 1360128 | 967800 | 466300 | 578800 | 686700 | 1288200 | 932600 |
| | Yield (qq/mz) | 13,1 | 10,7 | 10,6 | 12,3 | 10,4 | 16,2 | 10,6 | 19,5 | 8,4 | 13,8 | 13,0 | 9,9 | 10,9 | 10,0 | 10,0 | 11,5 | 9,8 |
| **Sorghum** | Area (mzs.) | 11883 | 6604 | 7942 | 5528 | 4199 | 6103 | 11354 | 8137 | 10970 | 6192 | 1907 | 4000 | 8902 | 5900 | 8836 | 5999 | 5793 |
| | Prod. (qq) | 172632 | 95842 | 125488 | 70477 | 61423 | 98361 | 176648 | 161652 | 141795 | 77873 | 39171 | 92000 | 284900 | 122800 | 184900 | 125700 | 117000 |
| | Yield (qq/mz) | 14,5 | 14,5 | 15,8 | 12,7 | 14,6 | 16,1 | 15,6 | 19,9 | 12,9 | 12,6 | 20,5 | 23,0 | 32,0 | 20,8 | 20,9 | 21,0 | 20,2 |
| **Rice** | Area (mzs.) | 3107 | 8328 | 5970 | 3817 | 5613 | 8862 | 7573 | 9948 | 6464 | 13550 | 15910 | 13300 | 12100 | 12000 | 10650 | 13880 | 14424 |
| | Prod. (qq) | 57038 | 239410 | 188438 | 145233 | 239616 | 311835 | 250323 | 347094 | 240415 | 456728 | 574931 | 397100 | 360000 | 284700 | 226600 | 356640 | 372983 |
| | Yield (qq/mz) | 18,4 | 28,7 | 31,6 | 38,0 | 42,7 | 35,2 | 33,1 | 34,9 | 37,2 | 33,7 | 36,1 | 29,9 | 29,8 | 23,7 | 21,3 | 25,7 | 25,9 |
| **Sesame** | Area (mzs.) | 59 | 151 | 3 | .. | .. | 1 | 5 | 33 | 6 | 23 | .. | .. | .. | .. | .. | .. | 191 |
| | Prod. (qq) | 541 | 1780 | 22 | .. | .. | 9 | 41 | 253 | 44 | 150 | .. | .. | .. | .. | .. | .. | 3134 |
| | Yield (qq/mz) | 9,2 | 11,8 | 7,3 | .. | .. | 9,0 | 8,2 | 7,7 | 7,3 | 6,5 | .. | .. | .. | .. | .. | .. | 16,4 |
| **Coffee** | Area (mzs.) | 4414 | 3688 | 3542 | 3013 | 3060 | 3112 | 4000 | 5024 | 5420 | 5730 | 5730 | 5738 | 5851 | 3200 | 4852 | 5450 | 4794 |
| | Prod. (qq) | 18353 | 15339 | 10595 | 12757 | 14514 | 14652 | 18299 | 34579 | 27277 | 22305 | 26788 | 26300 | 12400 | 13077 | 16253 | 16938 | 20582 |
| | Yield (qq/mz) | 4,2 | 4,2 | 3,0 | 4,2 | 4,7 | 4,7 | 4,6 | 6,9 | 5,0 | 3,9 | 4,7 | 4,6 | 2,1 | 4,1 | 3,3 | 3,1 | 4,3 |
| **Cotton** | Area (mzs.) | 245 | .. | .. | 101 | 469 | 239 | .. | 100 | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| | Prod. (qq) | 7403 | .. | .. | 4581 | 16329 | 7170 | .. | 1179 | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| | Yield (qq/mz) | 30,2 | .. | .. | 45,4 | 34,8 | 30,0 | .. | 11,8 | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| **Sugar** | Area (mzs.) | 1390 | 419 | 468 | 315 | 321 | 84 | 79 | 113 | 126 | 126 | 126 | 440 | 440 | .. | .. | .. | .. |
| | Prod. (qq) | 25966 | 8681 | 11123 | 5391 | 5468 | 2002 | 1655 | 3671 | 4693 | 3796 | 3796 | 13200 | 13200 | .. | .. | .. | .. |
| | Yield (qq/mz) | 18,7 | 20,7 | 23,8 | 17,1 | 17,0 | 23,8 | 20,9 | 32,5 | 37,2 | 30,1 | 30,1 | 30,0 | 30,0 | .. | .. | .. | .. |

# Region VI

| | | 1965-66 | 1970-71 | 1975-76 | 1976-77 | 1977-78 | 1978-79 | 1979-80 | 1980-81 | 1981-82 | 1982-83 | 1983-84 | 1984-85 | 1986-87 | 1987-88 | 1988-89 | 1989-90 | 1990-91 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Beans** | Area (mzs.) | 16683 | 21008 | 33441 | 37739 | 35079 | 51891 | 19779 | 18142 | 20228 | 23410 | 33972 | 38100 | 41768 | 25236 | 46196 | 41702 | 50178 |
| | Prod. (qq) | 186758 | 236204 | 313935 | 384080 | 380706 | 729442 | 147948 | 145412 | 164654 | 266666 | 307689 | 453000 | 385000 | 238590 | 360300 | 465000 | 533700 |
| | Yield (qq/mz) | 11,2 | 11,2 | 9,4 | 10,2 | 10,9 | 14,1 | 7,5 | 8,0 | 8,1 | 11,4 | 9,1 | 11,9 | 9,2 | 9,5 | 7,8 | 11,2 | 10,6 |
| **Maize** | Area (mzs.) | 75023 | 74484 | 89967 | 97069 | 97005 | 106854 | 48951 | 44520 | 83091 | 71960 | 83707 | 89500 | 80463 | 80830 | 97148 | 100385 | 90321 |
| | Prod. (qq) | 1011894 | 1049429 | 1340560 | 1222605 | 1420245 | 1794320 | 603378 | 587579 | 974138 | 1169493 | 1284748 | 1109200 | 1475500 | 1731170 | 1916000 | 1977900 | 1758100 |
| | Yield (qq/mz) | 13,5 | 14,1 | 14,9 | 12,6 | 14,6 | 16,8 | 12,3 | 13,2 | 11,7 | 16,3 | 15,3 | 12,4 | 18,3 | 21,4 | 19,7 | 19,7 | 19,5 |
| **Sorghum** | Area (mzs.) | 10885 | 8772 | 20317 | 4943 | 4871 | 4552 | 7828 | 7088 | 9661 | 3217 | 4167 | 6400 | 7655 | 4405 | 4498 | 6307 | 1578 |
| | Prod. (qq) | 143424 | 157906 | 343455 | 58470 | 76331 | 79647 | 130458 | 67822 | 174527 | 62309 | 136921 | 203700 | 230000 | 93500 | 131300 | 119100 | 42500 |
| | Yield (qq/mz) | 13,2 | 18,0 | 16,9 | 11,8 | 15,7 | 17,5 | 16,7 | 9,6 | 18,1 | 19,4 | 32,9 | 31,8 | 30,0 | 21,2 | 29,2 | 18,9 | 26,9 |
| **Rice** | Area (mzs.) | 750 | 3266 | 5107 | 4312 | 2831 | 5600 | 4909 | 4262 | 6187 | 6888 | 7615 | 6600 | 7700 | 7300 | 6030 | 4850 | 5523 |
| | Prod. (qq) | 10570 | 131823 | 182221 | 180683 | 123820 | 206079 | 163140 | 169629 | 226678 | 293800 | 297397 | 279700 | 285100 | 245600 | 189100 | 174550 | 204317 |
| | Yield (qq/mz) | 14,1 | 40,4 | 35,7 | 41,9 | 43,7 | 36,8 | 33,2 | 39,8 | 36,6 | 42,7 | 39,1 | 42,4 | 37,0 | 33,6 | 31,4 | 36,0 | 37,0 |
| **Sesame** | Area (mzs.) | 389 | 478 | 38 | 70 | 112 | 112 | 3 | 49 | 9 | 51 | .. | .. | .. | .. | .. | 71 | 191 |
| | Prod. (qq) | 3443 | 5539 | 354 | 735 | 1015 | 1028 | 26 | 473 | 89 | 388 | .. | .. | .. | .. | .. | 1110 | 3134 |
| | Yield (qq/mz) | 8,9 | 11,6 | 9,3 | 10,5 | 9,1 | 9,2 | 8,7 | 9,7 | 9,9 | 7,6 | .. | .. | .. | .. | .. | 15,6 | 16,4 |
| **Coffee** | Area (mzs.) | 60158 | 76242 | 114712 | 97489 | 99019 | 100240 | 60000 | 62000 | 59345 | 59700 | 59700 | 61957 | 57626 | 54163 | 51370 | 48827 | 48716 |
| | Prod. (qq) | 331049 | 397610 | 485524 | 583151 | 661901 | 668162 | 613706 | 751597 | 808813 | 912189 | 691644 | 746100 | 634200 | 509089 | 622999 | 493248 | 360862 |
| | Yield (qq/mz) | 5,5 | 5,2 | 4,2 | 6,0 | 6,7 | 6,7 | 10,2 | 12,1 | 13,6 | 15,3 | 11,6 | 12,0 | 11,0 | 9,4 | 12,1 | 10,1 | 7,4 |
| **Cotton** | Area (mzs.) | 4231 | 2481 | .. | 1689 | 2367 | 575 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| | Prod. (qq) | 116309 | 92173 | .. | 41634 | 46974 | 17273 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| | Yield (qq/mz) | 27,5 | 37,2 | .. | 24,7 | 19,8 | 30,0 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| **Sugar** | Area (mzs.) | 4921 | 3242 | 3997 | 4492 | 4551 | 769 | 723 | 1124 | 1252 | 1252 | 1252 | 2200 | 2200 | .. | .. | .. | .. |
| | Prod. (qq) | 103890 | 66045 | 88258 | 77808 | 79832 | 10035 | 7801 | 21257 | 24615 | 37573 | 37573 | 66000 | 66000 | .. | .. | .. | .. |
| | Yield (qq/mz) | 21,1 | 20,4 | 22,1 | 17,3 | 17,5 | 13,0 | 10,8 | 18,9 | 19,7 | 30,0 | 30,0 | 30,0 | 30,0 | .. | .. | .. | .. |
| **Tobacco** | Area (mzs.) | .. | .. | .. | .. | .. | .. | .. | 168 | 154 | 134 | 134 | .. | .. | .. | .. | .. | .. |
| | Prod. (qq) | .. | .. | .. | .. | .. | .. | .. | 4075 | 3807 | 3577 | 4071 | .. | .. | .. | .. | .. | .. |
| | Yield (qq/mz) | .. | .. | .. | .. | .. | .. | .. | 24,3 | 24,7 | 26,7 | 30,4 | .. | .. | .. | .. | .. | .. |

## Appendix 3. Soil density factors.

| | Region I | Region II | Region III | Region IV | Region V | Region VI |
|---|---|---|---|---|---|---|
| Beans | 1,0 | 1,0 | 0,9 | 0,90 | 1,0 | 1,0 |
| Maize | 1,0 | 0,9 | 0,9 | 0,90 | 1,0 | 1,0 |
| Sorghum | 1,0 | 0,9 | 0,9 | 0,90 | 1,0 | 1,0 |
| Rice | 1,0 | 1,1 | 1,1 | 1,10 | 1,1 | 1,1 |
| Sesame | .. | 1,0 | 1,0 | 1,0 | .. | .. |
| Coffee | 1,0 | 0,9 | 0,9 | 0,9 | 1,0 | 1,1 |
| Cotton | .. | 0,9 | 0,9 | 1,0 | .. | .. |
| Sugar | 1,0 | 1,0 | 1,0 | 1,0 | .. | 1,0 |
| Tobacco | 1,1 | 0,9 | 1,0 | 0,9 | .. | 1,1 |
| Vegetables | 1,0 | .. | .. | .. | .. | 1,1 |
| Pasture | 1,0 | 1,1 | 1,0 | 1,1 | 1,1 | 1,0 |

## Appendix 4. Use of fertilizer and pesticides.

Fertilizer and pesticides are input factors in agricultural production. The use of these input factors depends on their prices relative to other input factors. It is relevant in economic and environmental terms to incorporate variables for agrochemicals in the production function itself. However, the macroeconomic model available at present is not that specific in describing the behaviour of agricultural producers. A more rough approximation could be to link the input of agrochemicals to the level of production within each crop, based on constant input coefficients for use of fertilizer and pesticides. If this was done for each agricultural sector, the effects of structural change on use of fertilizer and pesticides would be incorporated in the model.

After a period of heavy subsidies on agrochemicals in the 80's, prices in Nicaragua are again roughly reflecting world market prices. Also other prices and the exchange rate are brought in touch with the free market levels. Thus, after a few years under the new price regime, input of agrochemicals are now likely to be stabilized at a level that is relevant for the years to come. If a price rise should occur, the input coefficients must obviously be adjusted. If small farmers' access to credit is improved, the use of agrochemicals may rise in certain cultivations, e.g. maize and beans. This should be considered in policy studies. Table A.1 shows preliminary coefficients in a linear sub-model of agricultural inputs.

The data presented below are not statistical data and are not directly useful as coefficients. However, they provide information which calibrated with other sources of information could provide coefficients for submodels of agrochemicals. The data are taken from the annual survey of production costs in different crops and technologies in Nicaragua (Costos agricolas 92/93, Banco Nacional de Desarollo) made by the state bank which is the main creditor of agricultural loans. The survey is a basis for evaluating applications for loans.

**Table A 4.1. Use of pesticides. Liters per ha.**

| Crop | Insecticides | Herbecides | Fungicides | Adherentes | Biologicos |
|---|---|---|---|---|---|
| Cotton | 14,5 | 4,8 | | | 1,8 |
| Sesame | 2,1 | 0,4 | | | |
| Soya | 2,3 | 1,8 | | | 1,1 |
| Sugarcane | 21,1 | 2,5 | | | |
| Coffee | 1,2 | 3,6 | 3,5 | 1,0 | |
| Tobacco | 14,9 | 3,7 | 111,1 | 1,8 | 0,8 |
| Maize | 7,3 | 1,6 | 2,8 | 0,9 | |
| Beans | 7,2 | 1,1 | 1,9 | 4,1 | |
| Rice | 4,8 | 2,0 | 4,4 | 0,4 | |
| Sorghum | 1,2 | 0,9 | 3,8 | | |
| Other | 3,9 | 1,7 | 12,7 | 0,3 | 0,1 |

**Table A 4.2. Estimated use of fertilizer by crop and technology. Nitrogen (N), phosfor (P) and potassium (K) 1992.**

| | | Kg/manzana | | | | | | Fraction |
|---|---|---|---|---|---|---|---|---|
| | | Kg/mz | N | P | K | Mg | B | of area |
| Alogodon technificado | Mix | 90.9 | 15.5 | 17 | | | | |
| | Urea | 68.175 | 31.4 | | | | | |
| | Am.sulph. | 68.175 | 14.3 | | | | | |
| | | | 61.1 | 17 | | | | 1 |
| Ajonjoli | Mix | 90.9 | 13.6 | 5.9 | 11 | | | |
| | Urea | 90.9 | 41.8 | | | | | |
| | | | 55.4 | 5.9 | 11 | | | 1 |
| Azucar | Urea | 181.8 | 83.6 | | | | | |
| Cafe ren 1. | Mix | 45.45 | 9.09 | 3.9 | | | | |
| | Urea | 22.725 | 10.5 | | | | | |
| | Foliar | 1.36 | 0.63 | | | | | |
| | | | 20.2 | 3.9 | | | | 0.04 |
| Cafe ren 2. | mix | 272.7 | 54.5 | 23 | | | | |
| | Urea | 136.35 | 62.7 | | | | | |
| | Foliar | 7.27 | 3.34 | | | | | |
| | | | 121 | 23 | | | | 0.04 |
| Cafe ren 3. | Mix | 545.4 | 98.2 | 14 | 54 | | | |
| | urea | 181.8 | 83.6 | | | | | |
| | foliar | 10.91 | 5.02 | | | | | |
| | | | 187 | 14 | 54 | | | 0.04 |
| Cafe ren.4. | mix | 545.4 | 98.2 | 14 | 54 | | | |
| | urea | 181.8 | 83.6 | | | | | |
| | foliar | 11.82 | 5.44 | | | | | |
| | | | 187 | 14 | 54 | | | 0.04 |
| Cafe techn. | mix | 545.4 | 98.2 | 14 | 54 | | | |
| | urea | 272.7 | 125 | | | | | |
| | foliar | 11.82 | 5.44 | | | | | |
| | | | 229 | 14 | 54 | | | 0.22 |
| Cafe semi | mix | 227.25 | 40.9 | 5.9 | 22 | | | |
| | urea | 227.25 | 105 | | | | | |
| | foliar | 0.18 | 0.08 | | | | | |
| | | | 33.5 | 1.3 | 5.1 | | | 0.23 |
| Cafe trad | | | | | | | | 0.22 |
| Cafe mejor 1. | mix | 363.6 | 65.4 | 7.8 | 45 | | | |
| | urea | 227.25 | 105 | | | | | |
| | foliar | 2.73 | 1.26 | | | | | |
| | | | 171 | 7.8 | 45 | | | 0.04 |
| Cafe mejo. 2. | mix | 409.05 | 73.6 | 8.8 | 50 | | | |
| | urea | 227.25 | 105 | | | | | |
| | foliar | 10.91 | 5.02 | | | | | |
| | | | 183 | 8.8 | 50 | | | 0.04 |
| Cafe mejor 3. | mix | 545.4 | 98.2 | 12 | 67 | | | |
| | urea | 181.8 | 83.6 | | | | | |
| | foliar | 2.73 | 1.26 | | | | | |
| | | | 183 | 12 | 67 | | | 0.04 |
| Cafe recup1 | mix | 272.7 | 49.1 | 7 | 27 | | | |
| | urea | 136.35 | 62.7 | | | | | |
| | foliar | 5.71 | 2.63 | | | | | |
| | | | 114 | 7 | 27 | | | 0.03 |
| Cafe recup2 | mix | 272.7 | 49.1 | 7 | 27 | | | |
| | urea | 136.35 | 62.7 | | | | | |
| | foliar | 5.71 | 2.63 | | | | | |
| | | | 114 | 7 | 27 | | | 0.03 |
| Cafe recup3. | mix | 545.4 | 98.2 | 14 | 54 | | | |
| | urea | 272.7 | 125 | | | | | |
| | foliar | 11.82 | 5.44 | | | | | |
| | | | 229 | 14 | 54 | | | 0.03 |
| Tabaco Americano | mix | 22.725 | 2.73 | 2.3 | 2.2 | | | |
| | nitr.de potas | 204.525 | 26.6 | | 77 | | | |
| | urea | 90.9 | 41.8 | | | | | |
| | H.semilla de alg | 1136.25 | | | | | | |
| | mix | 159.075 | 28.6 | 31 | | | | |
| | | | 99.8 | 34 | 79 | | | 0.2 |
| Tabaco burley | mix | 818.1 | 147 | 18 | 81 | | | |
| | nitr d. amonia | 340.875 | 116 | | | | | |
| | sulf.de potas | 90.9 | | | 31 | | | |
| | | | 263 | 18 | 111 | | | 0.2 |

| | Kg/manzana | | |
|---|---|---|---|
| | N | P | K |
| Cotton | 61.1 | 17.2 | |
| Sesame | 55.4 | 5.9 | 11.2 |
| Sugarcan | 181.8 | 83.6 | |
| Coffee | 113.9 | 7.6 | 27.0 |
| Tobacco | 133.7 | 18.4 | 80.7 |
| Maize | 79.1 | 18.0 | |
| Beans | 17.7 | 18.5 | 0.7 |
| Rice | 55.1 | 5.4 | |
| Sorghum | 58.7 | 11.7 | |
| Other | 100.0 | 25.0 | 8.0 |

| | Kg/hectare | | |
|---|---|---|---|
| | N | P | K |
| Cotton | 42.8 | 12.0 | |
| Sesame | 38.8 | 4.1 | 7.8 |
| Sugarcan | 127.3 | 58.5 | |
| Coffee | 79.7 | 5.3 | 18.9 |
| Tobacco | 93.6 | 12.9 | 56.5 |
| Maize | 55.4 | 12.6 | |
| Beans | 12.4 | 12.9 | 0.5 |
| Rice | 38.6 | 3.8 | |
| Sorghum | 41.1 | 8.2 | |
| Other | 70.0 | 17.5 | 5.6 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Tabaco hab.sol | mix | 90,9 | 16,4 | 18 | | |
| | urea | 45,45 | 20,9 | | | |
| | nitr d. ptas | 90,9 | 11,8 | | 34 | |
| | mix | 20,4525 | 3,68 | 0,4 | 2 | |
| | | | 52,8 | 18 | 36 | 0,2 |
| Tabaco virg. sec aire | mix | 477,225 | 85,9 | 10 | 47 | |
| | nitr d.amon | 163,62 | 55,6 | | | |
| | sulph.d. potas | 113,625 | | | 38 | |
| | | | 142 | 10 | 85 | 0,2 |
| Tabaco virg. horn de ri | mix | 545,4 | 98,2 | 12 | 54 | |
| | nitrato d.potas | 99,99 | 13 | | 38 | |
| | | | 111 | 12 | 91 | 0,2 |
| Maiz | mix | 90,9 | 16,4 | 18 | | |
| | urea | 136,35 | 62,7 | | | |
| | | | 79,1 | 18 | | 1 |
| Frijol tech.mach y riego | mix | 90,9 | 16,4 | 18 | | 0,8 |
| Frijol semilla tech mach | mix | 136,35 | 23,2 | 21 | 3,4 | 0,2 |
| Arroz tech secano-mac | mix | 45,45 | 8,18 | 9 | | |
| | urea | 136,35 | 62,7 | | | |
| | | | 70,9 | 9 | | 0,6 |
| Arroz tech sec. bueyes | urea | 90,9 | 41,8 | | | 0,2 |
| Arroz tech bueyes sec | urea | 45,45 | 20,9 | | | 0,2 |
| Sorgo tech riego | mix | 90,9 | 16,4 | 18 | | |
| | urea | 136,35 | 62,7 | | | |
| | | | 79,1 | 18 | | 0,3 |
| Sorgo tech mach | mix | 45,45 | 8,18 | 9 | | |
| | urea | 90,9 | 41,8 | | | |
| | | | 50 | 9 | | 0,4 |
| Sorgo tech bueyes | mix | 45,45 | 8,18 | 9 | | |
| | urea | 90,9 | 41,8 | | | |
| | | | 50 | 9 | | 0,3 |
| Cebolla mach. | mix | 363,6 | 43,6 | 38 | 36 | |
| | urea | 181,8 | 83,6 | | | |
| Chiltoma tech bueyes | mix | 272,7 | 32,7 | 35 | 22 | |
| | urea | 181,8 | 83,6 | | | |
| Lechuga tech.bueyes | mix | 272,7 | 32,7 | 35 | 22 | |
| | urea | 272,7 | 125 | | | |
| Repollo cons tech mac | mix | 272,7 | 32,7 | 35 | 22 | |
| | urea | 272,7 | 125 | | | |
| Tomate ind. tech mach | mix | 272,7 | 32,7 | 35 | 22 | |
| | urea | 136,35 | 62,7 | | | |
| | sulph d amon | 45,45 | 9,54 | | | |
| | Sandoflor | 6 | | | | |
| Tomate d. mesa, buey | mix | 545,4 | 81,8 | 35 | 67 | |
| | Sandoflor | 4,4 | | | | |
| Zanaoria tech mach ri | mix | 272,7 | 40,9 | 18 | 34 | |
| | urea | 181,8 | 83,6 | | | |
| Ajo tech mach para se | mix | 363,6 | 43,6 | 47 | 30 | |
| | urea | 227,25 | 105 | | | |
| Papa cons mach sec y | mix | 363,6 | 65,4 | 72 | | |
| | urea | 181,8 | 83,6 | | | |
| | Foliar | 12 | 5,52 | | | |
| Papa semilla tech mac | mix | 363,6 | 65,4 | 72 | | |
| | urea | 136,35 | 62,7 | | | |
| | Foliar | 26,4 | 12,1 | | | |
| Girasol | Mix | 90,9 | 10,9 | 12 | 7,5 | |
| | Urea | 45,45 | 20,9 | | | |
| Mani | Mix | 90,9 | 10,9 | 12 | 7,5 | |
| Soya | Mix | 90,9 | 10,9 | 12 | 7,5 | |
| | | 99,0759 | 24,4 | 8,2 | 5 | |

**Appendix 5. The Applied General Equilibrium model for Nicaragua and list of variables.**

**The price block**

$$PM_i = pwm_i * er * (1 + tm_i) \quad (6)$$

$$PE_i * (1 + te_i) = pwe_i * er \quad (7)$$

$$PC_i * XC_i = PD_i * XD_i + PM_i * M_i \quad (8)$$

$$P_i * X_i = PD_i * XD_i + PE_i * E_i \quad (9)$$

$$P_i * (1 - tv_i) = PV_i + \sum_j a_{ji} * PC_j \quad (10)$$

$$PK_i = \sum_j PC_j * imat_{ji} \quad (11)$$

$$COST_j = \sum_i PC_i * a_{ij} + W_j * LC_j \quad (12)$$

$$IPC_k = \frac{\sum_i PC_i * CD_{ik}}{\sum_i CD_{ik}} \quad (13)$$

$$IPCTOT = \frac{\sum_k \sum_i PC_i * CD_{ik}}{\sum_k \sum_i CD_{ik}} \quad (14)$$

$$INFLAC_t = \frac{IPCTOT_t}{IPCTOT_{t-1}} - 1 \quad (15)$$

**Production and factor demand**

$$X_i = ad_i * L_i^{\alpha_i} * KF_i^{1-\alpha_i} \qquad (16)$$

$$W_i * L_i = X_i * PV_i * \alpha_i \qquad (17)$$

$$X_e = at_e * (\gamma_e * E_e^{\rho_e} + (1-\gamma_e) * XD_e^{\rho_e})^{\frac{1}{\rho_e}} \qquad (18)$$

$$\frac{E_e}{XD_e} = \left(\frac{PE_e}{PD_e} * \frac{1-\gamma_e}{\gamma_e}\right)^{\frac{1}{\rho_e - 1}} \qquad (19)$$

$$XC_m = ac_m * (\delta_m * M_m^{-\rho_m} + (1-\delta_m) * XD_m^{-\rho_m})^{\frac{-1}{\rho_m}} \qquad (20)$$

$$\frac{M_m}{XD_m} = \left(\frac{PD_m}{PM_m} * \frac{\delta_m}{1-\delta_m}\right)^{\frac{1}{1+\rho_m}} \qquad (21)$$

$$DI_i = \sum_j a_{ij} * X_j \qquad (22)$$

**Income and consumption**

$$GAN_i=(P_i*(1-tv_i))-COST_i)*X_i \quad (23)$$

$$Y_{wk}=\sum_i W_i*L_i+er*trxk_{wk} \quad (24)$$

$$Y_{cp}=\sum_r dgc_r*GAN_r \quad (25)$$

$$Y_{pr}=\sum_u dgsi*GAN_u+er*trxk_{pr} \quad (26)$$

$$Y_{kp}=\sum_r (1-dgc_r)*GAN_r+\sum_u (1-dgsi_u)*GAN_u+er*trxk_{kp} \quad (27)$$

$$SUBG_k=\sum_i CSUB_{ik}*PC_i \quad (28)$$

$$PC_i*CD_{ik}=PC_i*CSUB_{ik}+Q_{ik}*(EXPEND_k-SUBG_k) \quad (29)$$

$$EXPEND_k=(1-s_k)*(1-td_k)*Y_k \quad (30)$$

$$SC_k=Y_k*(1-td_k)-EXPEND_k \quad (31)$$

**Government**

$$GR=\sum_i tv_i*P_i*X_i+\sum_i tm_i*er*pwm_i*M_i+\sum_k td_k*Y_k \quad (32)$$

$$GR=\sum_i PC_i*GD_i+\sum_i *er*pwe_i*E_i*te_i+SGOB \quad (33)$$

$$GD_i=betag_i*GDTOT \quad (34)$$

**Investment and saving**

$$KF_{i,t+1}=KF_{i,t}*(1-depre)+DK_{i,t} \tag{35}$$

$$INV=\sum_i PC_i*ID_i$$

$$STOT=\sum_k SC_k+sgob+er*sfor \tag{37}$$

$$INV=STOT \tag{38}$$

$$\sum_i PK_i*DK_i=INV \tag{39}$$

$$DK_i=kshare_i*DKTOT \tag{40}$$

$$ID=\sum_j imat_{ij}*DK_j \tag{41}$$

**Equilibrium of demand and supply**

$$XC_i=DI_i+\sum_k CD_{ik}+GD_i+ID_i \tag{42}$$

**Labour market**

$$LS=LR+LU \tag{44}$$

$$LR_{t+1}=LR0*\left[\frac{\frac{Y_{cp,t}}{Y_{cp,t-1}}}{\frac{Y_{wk,t}}{Y_{wk,t-1}}}\right]^{\gamma_1} \tag{43}$$

$$LS_t = ls0 * (1+g)^t \tag{45}$$

$$DES = LU - \sum_u L_u \tag{46}$$

$$L_i = LC_i * X_i \tag{47}$$

$$W_i = W_{i,t-1} * IPC_{wk,t-1} * index_i \tag{48}$$

**List of variables.**

**Endogenous variables:**

| | |
|---|---|
| $SUB_k$ | = Basic consumption by social class |
| $P_i$ | = Output price |
| $PD_i$ | = Domestic price of commodity i |
| $X_i$ | = Production of commodity i |
| $IPC_k$ | = Consumer price index for class k |
| IPCTOT | = Consumer price index |
| INFLAC | = Rate of inflation |
| $E_i$ | = Exports of commodity i |
| $PM_i$ | = Domestic price of competitive imports |
| $PE_i$ | = Domestic price of exports |
| $PC_i$ | = Composite price of domestic and imported commodities |
| $XC_i$ | = Composite commodity of domestic and imported products |
| $M_i$ | = Demand for imports |
| $XD_i$ | = National production for the domestic market |
| $PV_i$ | = Value added per unit |
| $PK_i$ | = Price of capital |
| $COST_i$ | = Unit cost |
| $W_i$ | = Wage rate |
| $LC_i$ | = Labour coefficient |
| $GAN_i$ | = Total profit in sector i |
| $L_i$ | = Demand for labour |
| LS | = Labour supply |
| LU | = Urban labour demand |
| LR | = Rural labour demand |
| DES | = Total unemployment |
| $DI_i$ | = Demand for intermediate commodities |
| $CD_{ik}$ | = Demand for commodity i by class k |
| $EXPEND_k$ | = Expenditure on consumption by class k |
| $Y_k$ | = Nominal income by class k |
| $SC_k$ | = Savings by class k |
| GR | = Total income to the government |
| $GD_i$ | = Government expenditure on commodity i |
| SGOB | = Government saving |
| INV | = Total nominal investment |

| | |
|---|---|
| $ID_i$ | = Investment by sector of origin |
| DKTOT | = Total investment |
| STOT | = Total saving |
| $DK_i$ | = Investment by sector of destination |
| $KF_i$ | = Capital by sector |

**Exogenous variables and parameters:**

| | |
|---|---|
| er | = Exchange rate |
| $a_{ij}$ | = Input-Output coefficient |
| $ad_i$ | = Shift parameter in Cobb-Douglas production function |
| $\alpha_i$ | = Cost share of labour |
| $at_i$ | = Shift parameter in export equation |
| $\tau_i$ | = Share parameter in export equation |
| $rho_e$ | = Transformation parameter in export equation |
| $pwm_i$ | = World price on competitive imports |
| $ac_i$ | = Shift parameter in import equation |
| $\delta_i$ | = Share parameter in import equation |
| $rho_m$ | = Elasticity of substitution |
| $betag_i$ | = Government expenditure coefficient |
| $tm_i$ | = Tax on competitive goods imports |
| $tmtot_i$ | = Total taxes on imports |
| $tvtot_i$ | = Total taxes on value added |
| $va_i$ | = Value added |
| $te_i$ | = Tariff rate on exports |
| $tv_i$ | = Tax on value added by exports |
| $index_i$ | = Wage indexation rule |
| $imat_{ij}$ | = Conversion matrix from destination to origin in investment |
| $kshare_i$ | = Share coefficient on total investment |
| $dgsi_i$ | = Distributional coefficient of profits for petty capitalists |
| $dgc_i$ | = Distributional coefficient of profits for campesinos |
| $dgw_i$ | = Distributional coefficient of wages |
| $q_{ik}$ | = Budget share of consumption by class |
| $s_k$ | = Marginal propensity to consume by class |
| $td_k$ | = Direct taxes on income |
| $csub_{ik}$ | = Basic consumption |
| sfor | = Foreign savings |
| depre | = Depreciation rate of capital |
| g | = Growth rate of labour force |
| $trxk_k$ | = Transfers from abroad by class k |
| gdtot | = Total government expenditure on goods and services |
| gamma1 | = Migration elasticity |