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Staff Paper

ENVIRONMENTAL ACCOUNTING FOR SUSTAINABLE DEVELOPMENT DECISIONS

John P. Hoehn

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Department of Agricultural Economics
MICHIGAN STATE UNIVERSITY
East Lansing , Michigan

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Standard indicators of economic growth reflect only a portion of a nation's productivity. The national accounting procedures that compute gross domestic product and net domestic product are based on concepts that view only market goods as scarce. They date to the early twentieth century when capital was the primary scarce good. Available human labor and environmental resources were considered the fixed, abundant gifts of nature. The scarcity of high quality labor--human capital--was not an issue and new deposits of natural resources always appeared available through discovery, political domination, or military conquest.

Environmental scarcity conditions, economic concerns, and international law have changed. Environmental goods are now globally scarce and in danger of neglect. Local environmental decay threatens human health and well-being in areas throughout the world. Global environmental change threatens uncertain dislocations for human society. Better indicators of economic performance are needed; indicators that account for the scarcity of environmental resources and reflect real tradeoffs involved in economic growth and development decisions.

Environmental accounts are one approach to understanding the link between economic and environmental change. Like the treatment of capital in standard accounts, environmental accounts treat environmental resources as one form of national wealth. The accounts identify available resources, measure investment and depreciation, and place an economic value on the services produced by such resources. The accounts place environmental resources on a level comparable to other forms of wealth.

Environmental accounts serve at least three purposes. First, the accounting process imposes organization on existing environmental information. Information is drawn together in an integrated framework. Second, the accounts identify the available quantity and quality of specific resources. Depreciation and investment can be tracked over time. Policy performance can be assessed. Third, a well developed accounting system identifies policy trade-offs across resources and across environmental and economic sectors. It place the environmental resources on a level comparable to other forms of economic wealth.

This paper examines environmental accounting procedures as a pragmatic method for analyzing and prioritizing environmental problems. Previous and on-going experiments in environmental accounting are reviewed briefly in the first section. The analysis then focuses on an accounting method for one set of resources--the soil resources of Uruguay.

The soil account grew out of a project jointly sponsored by the Uruguayan government and the Organization of American States. The project's purpose was to set policy priorities and identify appropriate analytical methods. Environmental accounts were one of the methods selected for further analysis. The purpose of the soil account was to examine the feasibility of environmental accounting as a tool for analyzing national policy alternatives.

The Structure of National Environmental Accounts

National income and product accounts are standard tools for managing national economies. Though their use by governmental analysts dates only to the 1940's, national economic accounts are now standard practice in virtually every country of the world.

Guidelines published by the United Nations Statistical Office (1979) give a standard framework for national income accounting. The United Nations accounts are encompass only environmental resources that are privately owned or are used in commercial production. These resources include tree plantations, soils, and mineral resources. Non-private resources such as air quality or stocks of wild species do not enter in the United Nations accounts.

The successes and failures of national economic accounting have encouraged a worldwide interest in the development of environmental accounting systems (see Ahmad, et al). In terms of successes, national economic accounts have proved to be exceedingly useful in organizing economic information, in identifying areas of growth and decay, and in analyzing economic policy alternatives. Systems of environmental accounts appear to share these same beneficial features.

In terms of failures, national economic accounts fail account for the economic value and depreciation of environmental resources. A recent report suggests that a "country could exhaust its mineral resources, cut down its forests, erode its soils, pollute its aquifers..., but measured [gross national] income would not be affected as these assets disappeared" (Repetto et al, 1989, p. 2). A key objective of environmental accounting is to overcome this shortcoming of standard economic accounts. Environmental accounts track the growth and depreciation of environmental resources and assist in identifying policies of long-term, sustainable growth.

Two general approaches to environmental accounting have emerged during the last twenty years. The first approach is to modify national economic accounts to incorporate directly the growth and depreciation of environmental resources. This approach has resulted in a number of interesting experiments in assessing the economic effects of environmental change (Bartelmus et al, 1992; Daly and Cobb, 1989; Nordhaus and Tobin, 1972; Peskin, 1976; Repetto et al, 1989; van Tongeren et al, 1991). Unfortunately, the purely economic approach confronts significant barriers when applied outside of special research studies. Economists have not yet reached a consensus on the relevant environmental services to include in the national income accounts nor are they agreed on shadow prices procedures that would be both operational and consistent with existing income accounts. This lack of consensus and a lack of data preclude the routine and immediate incorporation of environmental accounting into national income systems (Bartelmus, 1992).

The second approach is more evolutionary and pragmatic. This approach recognizes that there remain significant conceptual difficulties to incorporting environmental services fully into the national income accounts. These conceptual will take time to resolve. The second approach therefore uses the organizational and analytical tools of national accounting to develop an environmental information and analysis system. Instead of money, stocks and flows are first accounted for in physical units--measures such as hectares, cubic meters, milligrams per liter, and population counts. Where possible and necessary for policy analysis, economic valuation and shadow pricing procedures are used to convert physical units in money values.

Governments and their international organizations have generally adopted the evolutionary approach to environmental accounting. Canada, France, Germany, Japan, Norway, Sweden, and the United States are experimenting with this second approach. A recent World Bank publication recognizes that "environmental accounting in physical terms is essential" (Ahmad et al, 1989, p. 5) in development planning. The report argues for monetization when it is possible but suggests that, as an interim step, environmental accounts should be developed as a "satellite" system relative to the national income accounts. As a satellite system, the immediate goal of environmental accounting is to assist the development of effective environmental policy.

The remainder of this section examines the structure of alternative environmental accounts. The first subsection introduces the basic form of an environmental account. The second and third subsections review the accounting approaches taken by Norway and France. While most developed countries are experimenting with some form of environmental accounting, many of these are simply modified statistical information systems. In contrast, the Norwegian and French accounts were the result of an explicit and studied decision to develop systems of environmental accounting.

Accounting Principles

A key objective of environmental accounting is to structure environmental information in a way that is compact and easily intelligible. To this end, accounts are structured around three basic categories of environmental information. The first category is data on environmental stocks. Resource stocks range from quantities of mineral resources to biological resources such as forests and animal populations to qualitative resources such as water quality and coastal resources Descriptions of resource stocks may be in terms of mass (kilograms, tons), numbers of individuals (population counts), length (coastlines or river reaches), area (hectares, square kilometers), water or air quality (contaminant concentrations at a particular point in time), or economic value (dollars).

The second category of information describes resource investments. Investments are flow variables that augment resource stocks over a period of time. For instance, forests and animal populations grow at a particular rate. Growth rates measure the natural increase in a stock that occurs over a particular unit of time. Qualitative resources such as water or air quality also have a inherent capacity to cleanse themselves that may be viewed as a natural rate of investment or growth. Finally, investments certainly occur at the descretion of human beings. These decretionary investments include artificial stocking programs for wildlife or planting programs for forest resources.

The third category of information details resource depreciation. Like investment, depreciation is a flow variable. Analogous to the economic concept of depreciation, resource depreciation reduces the availability of a resource quantity or quality over a particular period of time. Depreciation results from resources uses such as mining and harvests as well as from natural events such as fire, flooding, and droughts. In addition, water and air pollution may be viewed as depreciation variables that diminish the stock of water and air quality.

Table 1 illustrates the structure of an account for a hypothetical forest resource. The rows of the Table 1 list entries for the initial resource stock at the beginning of a year, the additions to the stock that resulted from investments during a year, the reductions in the resource stock that result from depreciation, and, finally, the ending forest stock listed both in cubic meters and hectares.

The first numeric column in Table 1 lists stocks and flows for 1990. The year began with an intial stock of 40,000,000 cubic meters of timber or about 180,000 hectares of forest land. Natural growth resulted in the addition of 2,700,000 cubic meters and artificial plantings 600,000 cubic meters. The greatest reduction in stocks occured due to harvests for firewood. Other sources of depreciation included harvests for domestic lumber and pulp industries as well as for exports. Natural damage due to fire resulted in a relatively small reduction in the resource stock. At the end of the year, forest stocks had increased by 260,000 cubic meters.

The compact form of the resource account facilitates systematic policy analysis. For instance, Table 1 simulates the impact of two different firewood harvest rates for the period from 1991 to 2000. The second numeric column in Table 1 lists results for 2000 assuming that firewood harvest rates and all other investment and depreciation variables remain the same as in 1990. The final column lists results for 2000 assuming a policy that allows firewood harvests of 3,200,000 cubic meters per year while all other variables remain the same for the period from 1991 to 2000.

Table 1 shows that the two harvest policies affect forest stocks both directly and indirectly. The direct impact is depreciation due to firewood harvest--it increases by 500,000 cubic meters per year. The indirect impacts include less total growth and total fire damage since both are proportional to the size of the resource stock. The final result of increased depreciation and reduced growth is that forest stocks are about 15 percent smaller in 2000 under the higher harvest rate.

Options for reducing the impact of greater firewood harvests on forest stocks may also be considered using the data compiled in Table 1. Lumber, pulp, and export harvests could be reduced but these sources of depreciation are small relatively to the 500,000 cubic meter increase in firewood harvest. The most likely policy variable to offset increase firewood harvests would be increased investment due to increased plantings. Additional simulations could be constructed to examine the relative impacts of reduced depreciation versus increased plantings.

The data in Table 1 could also be converted to economic values using standard pricing techniques for timber (Repetto et al, 1989). Conversion to economic values would allow one to compare the relative economic benefits and costs of alternative forest investment and depreciation policies.

The key point of Table 1 is to illustrate the central features of a resource account. A standard account organizes resource data into consistent categories of stocks and flows and facilitates policy analysis once policy changes can be linked to changes in resource flows.

The Norwegian Resource Accounts[1]

Development of the Norwegian resource accounts began in the early 1970's with the creation of a new Norwegian Ministry of the Environment. The accounts were developed to parallel the policy concerns of the new Ministry. As policy tools, the Norwegian accounts do not attempt to develop a comprehensive description of environmental resources. Rather, they focus on the environmental resources that are of greatest political or economic interest.

Four criteria guided the selection of resources to be included in the accounting framework (Alsen et al, 1987):

a. The resource is politically or economically important.

b. Statistics for the resource were available or possible to establish at a reasonable cost.

c. It should be possible to demonstrate successful completion and use of the account in policy development and analysis.

d. Where a resource is included in both the national income and environmental accounts, the definitions used in the environmental accounts should be consistent with those used in the national income accounts.

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[1] Information regarding the Norwegian resource accounts was obtained from Alfsen et al (1987) and Garnasjordet (1983).

The pragmatic goals of the Norwegian accounts lead the Ministry of Environment to develop two general categories of accounts. The first category of accounts focuses on mineral and biotic resources. These include energy reserves (stocks) and flows by energy source, wood production flows, fish stocks and fish harvest. The physical stocks and flows for each mineral and biotic account are analogous to Table 1--each resource is covered by an detailed accounting of stocks, investments, and depreciation.

The second category within the Norwegian accounts addresses the environmental pollution and human activities that impinge on environmental quality. This category focuses on two specific accounts: air pollutant emissions and land use. An additional account for water quality was considered but rejected after researchers concluded that it would be too complex to manage at the national level. Special studies have been completed to examine solid and hazardous wastes, radiation, and noise.

The air emissions accounts include flow estimates for SO_2, NO_x, CO, and Pb at the national level and NH_3, HC, Cd, and Hg at the regional level. Emissions are calculated for seven sectors: paper and pulp industry, electrical power generation, other industrial sources, services, transportation, other commercial sectors, and households.

An interesting feature of the Norwegian air emssion accounts is that they are based primarily upon technical knowledge of the production processes used in each accounting sector. Engineering process models were constructed to relate the level of production or consumption in each sector to the level of emissions. Emissions data from field 30 monitoring stations were used to reconcile and calibrate the emissions estimates calculated from the process models. By combining engineering knowledge of production processes with limited monitoring data, the air emissions accounting framework substantially reduces the cost of environmental information.

The air emissions accounts are also inked to an economic framework of the demand and supply. This linkage allows Norwegian analysts to examine the benefits and costs of alternative air pollution control strategies for both a specific industry that may be subject to control as well as for the economy as a whole.

The Norwegian land use account tracks the use of both rural and urban land over time. Land use data is geocoded. Rural land use data are obtained from aerial photographs and existing land use maps. Urban land use data comes from municipal files. All land use data is geocoded and stored in a geographical information system. The rural data file is scaled to include 6,000 geographic data points while the urban file contains 135,000 data points.

From the lastest information available, the land use account appears to be primarily a inventory to track land use over time. It does not appear to have an analytical component that would allow analysts to examine how taxes, subsidies, infrastructure investments, or land use controls would affect future land use. Of course, the geographic coding system does appear flexible enough to be linked to analytical systems as the Norwegian policy needs and capabilities evolve.

The Norwegian system represents a conservative but generally effective approach to the development of environmental accounts. The accounts were designed to reflect the pragmatic goals of environmental policy and to ensure success when subject to limited human and financial resources. They were limited in scope and encompass only those resources that are of concern in the present and near future. The system makes effective use of monitoring data as well as engineering and economic knowledge.

The air emissions accounts appear to be the most successful of the Norwegian accouts. They appear to have been designed with a clear policy objectives in mind and they are actively used in analyzing alternative policies. They also make use of known engineering and economic relationship in order to reduce the need for and cost of field monitoring. In contrast, the land use accounts incorporate large quantities data but do not seem to be linked to specific policy objectives. The land use accounts appear to be largely an inventory of land use types rather than an analytical system.

The French Natural Patrimony Accounts[2]

The French natural patrimony accounts are an ambitious effort to develop a comprehensive description of the totality of French environmental stocks. The natural patrimony accounts are part of a even larger effort to develop a system of national patrimony accounts that incorporates environmental, industrial, commercial, and human stocks. Though part of the larger system, environmental stocks tend to be measured in physical units. Physical units are converted to monetary units only when environmental resources are explicitly sold into the industrial or commercial sectors.

An inter-ministry committee was set up in 1978 to guide the development of natural patrimony accounts. The committee was not constrained or guided by any immediate environmental policy objectives. Rather, the primary objectives were conceptual: to promote a general systems approach, to standardize information, and to supply agencies with decision making information. The committee apparently viewed itself as outside the domain of decision making.

The accounts divide environmental stocks into two categories: components and ecosystems. Components are resources as homogeneous sets of individuals. Within the component category there are accounts for non-renewable resources such as minerals and

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[2] Information regarding the French natural patrimony accounts was obtained from Teillet (1988) and Weber (1983).

subsoil resources, surface resources such as soil, water, and air, and for biological organisms such as wildlife. The structure of the component accounts is analogous Table 1.

The wildlife accounts are appended with an information card that includes estimates of a species' historical distribution area, its current distribution area, and its potential habitat area. A measure of how much is known about a species is calculated as (a) the area of an actual population count zone divided by (b) the potential habitat area. A measure of relative species protection is calculated as (a) the area in which a species is protected divided by (b) the species' potential habitat zone.

The ecosystem accounts are intended to identify characteristic systems of individuals. Ecosystems appear to be measured in terms of suface area and state of health. The form of the account is similar to Table 1 and shows, by ecosystem type, the initial stock, redeployment of surface area from one ecosystem to another, and final stock. Redeployment means an entry that shows that a given amount of surface area was taken out of a particular ecosystem and placed within another. For instance, draining of land for agricultural purposes would be noted as a reduction of in wetlands' surface area and an addition to an agricultural ecosystem stock. In this way, the French ecosystem account identifies trends in ecosystem extent and conflicts between ecosystem types.

The French natural partrimony accounts represent the successes and difficulties of a comprehensive approach to resource planning. The accounts seek to describe the totality of the French natural patrimony. They are consistent in their structure and conceptually innovative. However, in the attempt to be comprehensive and conceptually rigorous, the accounts spread limited human and financial resources over a very large task. Accounting complexity makes application to policy analysis difficult. Implementation is also slow. During the first five years of development, only three sets of accounts were actually implemented.

Environmental Accounting and Policy Analysis

An environmental account for agricultural soils in Uruguay illustrates how an account may be used estimate resource depreciation due to current practices. It also included analytical components that allow the examination of alternative technological and economic policies. The account was developed by the present author (Hoehn, 1990) during a brief consultation with the Uruguayan President's Planning and Budget Office and the Organization of American States.[1] The account was intended as preliminary effort to test how environmental accounting might be used to support national environmental policy decisions. As such, its purpose was to illustrate the basic structure and outputs of a soil depreciation account and to set guidelines for further developmental research.

Figure 1 illustrates the analytical structure of the Uruguayan soils account. National price policy affects agricultural product and input prices which in turn affect the profitability of agricultural crops. Farmers respond to economic policy by allocating more or less land to production as prices change. Technology policy is embodied in research and extension programs. These programs shift the technological options available to farmers. Acreages cultivated, technology, and soil properties combine to produce soil loss--depreciation--from agricultural lands. Eroded soils carry valuable nutrients off-site. Losses of soil and nutrients result in lost soil fertility as well as off-site effects. In Uruguay, major off-site effects include aquatic ecosystem changes, siltation of irrigation and hydroelectric reservoirs, higher costs of municipal water supply, and increased dredging for navigation.

The account structure was made empirically operational using three distinct components. The first component described the relationship between hectares planted, technology, soil properties, and soil loss. This relationship was modeled using the Universal Soil Loss Equation (USLE) (Novotny and Chesters, 1981; Salas, 1988). The second component used previous research to estimate the relationship between common Uruguayan soil management technologies and the CxP values of the USLE. The third component was economic and summarized the estimated relationship between nation agricultural price policies, crop profitability, and areas actually planted. The three components together permit an analyst to estimate how various price and technology options may affect net soil loss.

The overall model was based on an extensive body of soils research conducted during the last 20 years in Uruguay. This research included a comprehensive soils inventory (Direccion de Suelos y Fertilizantes, 1979). The inventory described the physical properties and spatial distribution of the more than 100 soil groups found in Uruguay. Additional previous research also specified the ULSE parameter values associated with soil management technologies as practiced in the Uruguayan setting (Puentes, 1983; Puentes and Szogi, 1983).[2]

The Basic Soil Loss Model

The USLE was used to model the core relationship between area planted, technology, soil properties, and soil loss. The USLE gives net soil loss for a cultivated area of size H as:

$$(1) \quad NSL = H(R)(K)(LS)(CxP) - T$$

where

NSL = soil erosion net of the soil tolerance level in metric tons per hectare per year,

H = area cultivated in hectares

R = a factor based on rainfall energy,

K = a factor summarizing the erodability of different soils obtained through laboratory or field experiments,

LS = a factor that accounts for topography,

CxP = a factor that accounts for crop cover and soil management practices, and

T = soil tolerance level.

The first term on the right hand side of equation (1) gives gross annual soil loss. The second term on the right hand side is the amount of annual soil loss that a particular soil type can tolerate without loosing is productive capacity. The result of subtracting the second term from the first term is the net amount of annual loss that impairs long-term soil productivity.

Representative values for each of the USLE variables were selected for each of the Uruguayan governmental departments. Cultivated area, H, was calculated for 1986 using census data and crop production data from the Uruguayan Ministry of Livestock, Agriculture, and Fisheries. Variables R through T were selected to be representive of agricultural soils in each department as described in the national soils inventory, *Carta de Reconocimiento de Suelos del Uruguay* (Direccion de Suelos y Fertilizantes, 1979).

Soil Management Technologies

The impact of management technology on soil erosion has been the subject of extensive research by Uruguayan soil scientists (Puentes, 1983; Puentes and Szogi, 1983). This research has identified CxP values for a range of technologies common to Uruguayan agriculture. The most erosive technology is traditional soil management characterized by continuous cultivation and conventional plowing. The spectrum of available technologies progresses through successively less erosive techniques based on various combinations of contour plowing, reduced tillage, rotation, and other soil management systems. The least erosive technology is maintenance of natural pasture.

No single soil management technology dominates Uruguayan crop production within any given department. Rather, within any department, different farms use different soil managment technologies. To account for this intra-departmental distribution of technologies, three technological groupings were defined. The first was a *traditional* technological grouping. In a department with a traditional technological grouping, 70 percent of crop soil area is managed with a continuous cultivation and conventional plowing. 30 percent is managed with continuous cultivation with some conservation management (e.g., contour plowing, grass strips). The second technological grouping was an *intermediate* mix. In a department with an intermediate grouping, crop areas are split 50-50 between the two technologies instead of the 70-30 split within the traditional group. The third grouping was a *conservation* management mix. In the conservation management grouping, only 10 percent of soils are managed with continuous cultivation/conventional plowing, 60 percent are worked with some conservation management, 20 percent are managed with reduced tillage, and 10 percent with a combination of rotation and conservation management.

The 19 governmental deparments in Uruguay were matched with the three technology groupings using the research and knowledge of Uruguayan soil scientists. A weighted average CxP value was calculated for each grouping using the CxP value for a specific technology and the porportion of land subject to that technology within a given type of department. The CxP values for the traditional, intermediate, and conservation groupings were, respectively, 0.433, 0.375, and 0.239.

The Economic Component

The economic component summarized the historical relationship between agricultural price policy, crop profitability, and hectares planted. A model of profit maximizing planting decisions was used to derive a reduced form response function for hectares planted in a given crop. The response function embodied the relationship between hectares planted, agricultural prices, and other variables such as weather conditions and technological change. For a given crop, the response function was specified as

$$(2) \qquad \ln(h) = \alpha_0 + \alpha_p \ln(p) + \alpha_a \ln(a)$$

where $\ln(\bullet)$ denotes the natural logarithm of the variable in parentheses, h is hectares planted in a given crop, p is the product price as set by agricultural policy, and a represents other variables that affect crop profitability. Since equation (2) is a reduced form, coefficients such as α_p are mixtures of structural parameters. It is therefore not possible to formulate any strong hypotheses regarding the anticipated signs of the coefficients.

Economic policies of subsidies and taxes were summarized in terms of their effects on input and product prices. Through input and product prices, equation (6) links economic policy to area planted. It also links economic policy to soil erosion since soil erosion is proportional to area planted. To examine the impact of economic policy on soil erosion, one requires an estimate of equation (2).

Equation (2) was econometrically estimated using annual data on the production of the 8 crops from 1965 to 1988. Producer price and area planted data were obtained from the Direccion de Programacion y Politica Agropecuaria (1990).[3] The 8 crops analyzed were barley, flax, maize, rice, sorghum, soybeans, sunflower, and wheat. The area planted in these 8 represented 70 percent of the land in agriculture. Since soil erosion in equation (1) is proportional to area planted, this means that the soil erosion estimates reported below represent approximately 70 percent of the total agricultural soil loss.

Seemingly unrelated least squares (Judge et al, 1980) was used to estimate equation (2) for each of the eight crops under study. The estimated price coefficients are are displayed in Table 2. The price coefficients are elasticities since all variables entered the statistical analysis in their logarithmic form. The largest price coefficient is for flax. A 10 percent increase in flax prices increases hectares planted by 11.3 percent. The smallest price elasticity is for barley. It is negative and suggests the barley acreage falls by 1.56 percent with a 10 percent increase in product price. The negative relationship for barley may imply that farmers have a tendency to substitute higher yields for increased hectares as price increases.

The statistical significance of the price coefficients was tested for the 8 equation system. The null hypothesis was that the price coefficients were each equal to zero. An F test with 140 and 8 degrees of freedom rejected the null hypothesis at the 95 percent level of significance. Hence, product price is a statistically significant variable in explaining the number of hectares planted.

The impact of a change in product price policy (e.g., a subsidy or tax) is estimated using equation (2) and the price coefficients in Table 2. Let the product price for a baseline scenario be represented by p^0 and the number of hectares planted be h^0. Let the product price under an alternative price policy be p^A. Using equation (2), the estimate of the number of hectares planted under the alternative price is, in logarithmic form,

$$\ln(h^a) = \ln(h^0) + \alpha p \ln(p^A) - \beta \ln(p^0) \tag{3}$$

or, taking the anti-logarithm of (3),

$$h^a = h^0(p^A/p^0)^\alpha . \tag{4}$$

Equation (4) gives the hectares planted, h^A for any alternative price policy that can be represented by p^A. For instance, an alternative policy that increases product prices relative to p^0 is represented by a p^A that is greater than p^0. An alternative policy the reduces subsidies or increases taxes is represented by a p^A that is less than p^0.

To calculate soil loss under alternative price policies, h^A is first estimated using equation 4. The estimate is used as an input into the basic soil loss model described above. By equation (1), soil loss for a given technology is proportional to hectares planted.

Technology and Price Policy Scenarios

Economic and technology policy are routinely analyzed for their impact on priced resources such as capital and labor. However, the effects of policy on nonmarket resources is often overlooked. In this section, two technological alternatives and two economic alternatives are examined for their impact on soil loss. Economic policy is described by its impact on product prices. Technology policy is described by the mix of soil management practices used across different departments. The baseline technology policy is the prevailing distribution of soil management technologies as described above. The baseline price policy is represented by 1986 domestic price subsidies relative to international border prices as reported in von Oven and Paysse (1988).

The first alternative technology scenario examines soil loss assuming a traditional technology mix is used in *all* departments. During the last 20 years, extensive extension and research efforts were made to improve soil management in Uruguay. This first scenario is intended to give an general idea of the impact of the achieved improvedments in soil management. With this scenario, 70 percent of the planted crop area is managed using continuous cultivation and conventional plowing and 30 percent is managed with continuous cultivation and some form of conservation management.

The second technological scenario examines the impact of further improvements in soil managment. It assumes all departments could be brought up to the mix of technologies that prevails in departments with the conservation grouping of technologies. This scenario assesses the reductions in soil depreciation that may be possible with available technology and further extension efforts.

Each technological scenario changes the CxP value associated with agricultural production in a given department. These CxP values were used as data to estimate net soil erosion using equation (1).

National economic policy affects domestic product prices. An economic policy may increase product prices through price supports or subsidies. As product prices increase, resources are used more intensively in the subsidized sector. In the subsidized sector, depreciation is likely to increase for both market and nonmarket resources. A reduction in subsidies or an increase in product price taxes is likely to have the opposite effect.

The first price scenario was intended to represent an economic policy without subsidies to agriculture. Effective producer prices were set to 10 percent less than international border prices. The 10 percent discount from border prices was intended to reflects the costs of marketing and transportation to the port in Montevideo.

The second price scenario represented a general increase in the level of subsidies. Internal product prices were assumed to be set at twice the level of border prices. Twice the border price was price support level for maize in 1986. It was the highest level of price support in that year.

Soil Loss under Alternative Policy Scenarios

Table 3 shows net soil loss under the baseline scenario and the two alternative price policies. In the baseline scenario 591 thousand hectares are planted and 13.97 million tons of soil are lost from agricultural lands. This translates to a loss of 24 tons per hectare or, on average, a little less than 2 millimeters of soil depth per year.[4]

Under the no subsidy scenario, the number of hectares planted and net soil loss declines by approximately 13 percent to 506 thousand hectares planted in the 8 crops and an annual net soil loss of 12.20 million tons. Under the high subsidy scenario, prices increase to twice their border price, hectares planted increase to 671 thousand hectares, and net soil erosion increases to 16.01 million tons. The increase in hectares planted and soil loss is approximately 15 percent more than the baseline level.

An analysis of gross soil loss and soil loss to water bodies showed that they respond to prices in a manner similar to net soil loss. Thus, under the no subsidy price policy, gross soil loss and soil loss to water bodies decline by approximately 13 percent. Under the high subsidy scenario, each increases by about 15 percent.

Table 4 gives net soil losses under the baseline scenario and the two alternative technology scenarios. The second column in Table 4 lists net soil loss under the baseline scenario. The third column lists net soil loss under the assumption that traditional soil management technology is used in all Uruguayan departments. Under this scenario, net soil loss increases by 54 percent relative to the baseline scenario. Net losses are 21.44 million tons per year or 36 tons per hectare. This translates to a loss of 2.9 millimeters of surface soil. Losses of organic matter, nitrogen, and phosphorus also increase by 54 percent under the traditional technology scenario. These results indicate that the diffusion of improved soil management technology to at least a portion of Uruguayan departments has achieved significant reductions in soil loss.

The fourth column in Table 4 lists net soil losses for the scenario that extends the technology currently used in conservation oriented departments to all Uruguayan departments. This conservation scenario reduces annual net soil loss to 9.98 million tons or by 29 percent relative to the baseline scenario. Net soil loss per hectare is 17 tons and the annual loss in terms of soil depth is 1.3 millimeters. Losses of organic matter, nitrogen, and phosphorus also decline by 29 percent. The scenario suggests that the extension of existing conservation technology to all departments would result in significant soil savings.

The last column in Table 4 combines the current conservation technology in all departments scenario with the no subsidy scenario. With this combined technology and economic policy scenario, net soil loss falls to 8.68 million tons per year from the baseline loss of 13.97 million tons per year. This is a reduction of 38 percent in net soil loss.

Identical reduction rates are obtained for net soil loss per hectare, organic matter, nitrogen, and phosphorus.

Policy Implications

The soil account developed in this study illustrates the potential contribution that environmental accounts can make to environmental policy. Uruguayan agencies maintain excellent basic data on soil types and uses. The basic problem for policy analysis is that the data are not easily accessible. The soil account organizes existing information in a policy relevant manner, keeps track of resource use and depreciation, and assists in analyzing policy alternatives.

The soil account suggests that economic and technology policy have a significant impact on soil loss in Uruguay. Net soil loss declines by 13 percent when the current mix of crop subsidies and taxes are shifted to a policy based on market prices. Soil loss declines by 29 percent when existing conservation technology are extended to all agricultural areas in Uruguay. A combined policy of market prices and the extension of existing conservation technologies to all departments may result in significant reductions in soil depreciaion.[5]

The results of the soil account analysis are preliminary. The account is based on data and assumptions that would be modified in a longer term research program. The account is primarily intended to outline the design of an environmental account and set a foundation for further research. Further research would attempt to price the impact of soil loss and to extend the accounts to soil erosion off-site effect on water quality, water impoundments, and navigational dredging.

Conclusions

Though they differ widely in specifics, environmental accounts share four prominent features in their design and construction. First, their primary objective is to provide information that is relevant to economic and environmental policy. This policy orientation implies that a system of accounts will address the environmental resources that are of greatest concern to the particular nation or agency that is responsible for developing the accounts. It also implies the detail and accuracy that are built into an accounting system are selected with policy analysis in mind. When the goal of policy analysis is forgotten, resources are easily misspent on unnecessary detail or in producing irrelevant information.

Second, environmental accounts focus attention on the question of sustainability. Investment is traced through savings, maintenance, and rehabilitation. Investment enhances capital, resource productivity, and future income possibilities. Depreciation occurs due to use, decay, and neglect. Depreciation reduces future productivity and income. In a fully monetized account, sustainable national income is expressed as consumption plus investment less depreciation.

Third, existing environmental accounts focus on the depreciation of private or semi-private resources. These resources include forest, energy resources, and soil. With these resources, consumption and investment are typically included in standard income accounts. The primary environmental accounting problem for these resources is to estimate a suitable measure of depreciation. This restriction to private and semi-private resources is largely due to the practical difficulties of measuring and valuing public resources such as air quality, water quality, or wild species. However, with appropriate research, these difficulties can be overcome and the accounts extended to purely public resources.

Finally, the development of an environmental accounting system is an evolutionary process. At the initial stages of the development process, policy concerns are identified and a small number of relevant accounts are proposed. Information sources are identified, the practicality of the proposed accounts is reviewed, and the needed research is begun. Initial accounts may be expressed in physical terms. Conversion to money valuation takes place at later stages of development.

Endnotes

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2. See Hoehn (1990) for a detailed discussion of Uruguayan soils and the procedures used to develop the account.

3. Product prices were assumed to be fixed by the international market in any given year. Effective producer price should therefore be exogenous and reflect the international price plus any government subsidy and less any tax.

4. Estimated losses of organic material, nitrogen, and phosphorus were proportional to total net soil loss. See Hoehn (1990).

5. Extension of conservation oriented technologies to traditional and intermediate departments would require research to adapt these technologies to different geophysical and socioeconomic conditions. The Instituto Nacional de Investigaciones Agropecuarias is developing such farming systems research at its experiment station in Canelones.

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Figure 1. Agricultural Soils Account

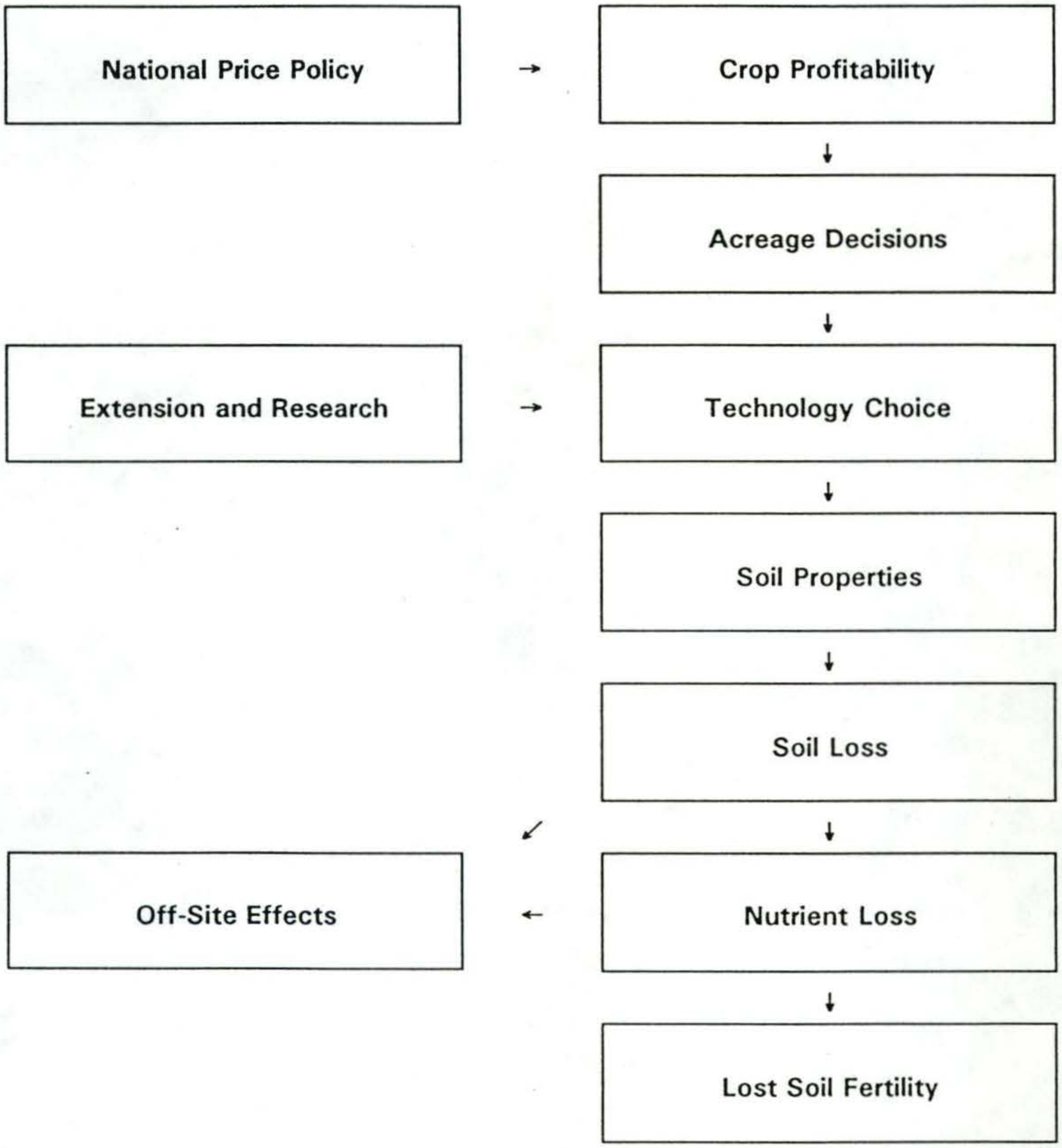

Table 1. A Forest Resource Account, 1990 to 2000

Statistic	Year 1990	Year 2000, Harvest Scenarios	
		2,700,000 m^3/year	3,200,000 m^3/year
Initial Stock (1000 m^3)	40,000	43,534	37,632
Investment (1000 m^3)			
Growth	2,700	2,939	2,540
Plantings	600	667	667
Total	3,300	3,606	3,207
Depreciation (1000 m^3)			
Firewood	-2,700	-2,700	-3,200
Lumber/Pulp	-200	-200	-200
Exports	-100	-100	-100
Natural Damage	-40	-44	-38
Total	-3,040	-3,044	-3,538
Ending Stock (1000 m^3)	40,260	44,096	37,301
Net Investment (1000 m^3)	270	4,096	-2,699

Table 2. Estimated Hectares-Price Elasticities for Uruguayan Crops

Crop	Price Elasticity
Wheat	0.361** (2.22)
Flax	1.13** (4.45)
Barley	-0.156** (-2.53)
Maize	0.436** (3.45)
Sunflower	0.308** (2.31)
Rice	0.172 (1.42)
Sorghum	0.894** (3.64)
Soybeans	1.07 (1.04)

Note: T-statistics for each coefficient are given in parenthesis. A"**" indicates that a coefficient is statistically different from zero at the 95 percent level of confidence.

Table 3. Net Soil Losses Under Different Price Scenarios and Prevailing Technology (8 crops)

Category	Baseline Scenario (at 1986 prices)	No Subsidy: Border Price Less 10%	High Subsidy: Twice the Border Price
Area Planted, 1000 hectares	591	506	671
Net Soil Loss above Tolerance			
Total, millions of tons	13.97	12.20	16.01
Change from Existing Loss (%)	0	-13	+15
Tons per hectare	24	24	24
Loss of Soil Depth, mm	1.9	1.9	1.9

Table 4. Net Soil Losses with Baseline Prices and Alternative Technologies (8 crops)

Category	Baseline Scenario (at 1986 prices)	Traditional Technology, All Depts.	Current Conservation Technology All Depts.	Current Conservation Technology, All Depts.; No Subsidy
Area Planted, 1000 hectares	591	591	591	506
Gross Soil Loss (GSL)				
Total in 1000 tons	13.97	21.44	9.98	8.68
Change from Existing Loss (%)	0	+54	-29	-38
Tons per hectare	24	36	17	17