COSTS OF SOIL EROSION FROM AN AREA OF HIGH AGRICULTURAL PRODUCTION

João Fernando Marques[1]

ABSTRACT - The impacts of soil erosion can be grouped into two major categories, off-site and on-site. The present study will focus on erosion damages at both areas of impact. The estimated economic cost of the off-site (external) costs of erosion will be based on the effect of water born sediment on hydroelectric plants. This effect can be lost reservoir capacity, increased use of maintenance labor, and reduced electrical energy production. The on-site (internal) costs of erosion will be determined by soil nutrient replacement costs. The monetary values of the on-site and off-site damages were calculated using lost revenue, replacement costs, and decreased system productivity. The empirical work was based on sediment levels in the Sapucaí River located in the Brazilian state of São Paulo's north. The estimated annual off-site costs, discounted at 3% per year, was US$ 9,854,490.00, larger than the US$ 5,377,913.00 for annual on-site costs.

Key words: Environmental Impacts, replacement cost, environmental Economics.

INTRODUCTION

Environmental science classifies the impact of soil erosion as either internal ("on-site") or external ("off-site") determined by the impact's place of origin. A great deal of literature has reported that off-site costs are larger than on-site costs (Clark II et al. 1985; Crosson, 1985;

[1] CNPMA/EMBRAPA's researcher. Address: Rodovia SP 340, Km 127,5, 13820-000, Jaguariúna - SP - Brazil.

Ribaudo, 1989; Marques, 1995; Montoya et al., 1994; Southgate & Macke, 1989). The identification of all the impacts of soil erosion is a very complex process. The difficulties in quantifying each damage is even more complex. (Menck, 1993; Sorrenson & Montoya, 1989; Montoya et al. ,1994; Southgate & Macke, 1989; Bastos Filho, 1995).

Replacement cost and sacrificed production are important alternative measures which can be used to quantify economic losses caused by the alteration of a natural environment. Even so, other components of total economic value - option and existence values - are not considered by replacement cost and lost production measurements. Regardless of what method is used to estimate costs, there is a high probability that the estimate will understate the economic value of the damage caused by environmental modification. However, as a pioneering study of the external and internal costs of erosion in Brazil, we sought a to develop our empirical research over a wide scope.

The present work intends to estimate some of the current costs of one type of environmental modification, agricultural production, in the Sapucaí Watershed. The effect of soil erosion on hydropower plant functioning and the loss of nutrients in the agricultural area were used to estimate this cost.

THE RIVER BASIN

The Sapucaí River Watershed begins in State of Minas Gerais and extends approximately 300 Km into the State of São Paulo's north. The watershed covers an area of approximately 6,570 km2, 6,000 km2 of which is in the state of São Paulo and includes segments of the following counties: Guaíra, Batatais, Franca, Guará, Ituverava, Patrocinio Paulista, Restinga, São José da Bela Vista, Altinópolis, Ipuã, Nuporanga, and São Joaquim da Barra. The watershed is a humid, subtropical region with dry winters and annual average precipitation of 1400 mm. Cultivated agricultural crops and pasture cover 93% of the area, and the remaining land has either been reforested or is covered with virgin forests. The Sapucaí River is a tributary of Grande River. The amount of solids suspended in the Sapucái River averaged 180,000 m3. Companhia Paulista de Força e Luz, CPFL, operates two small hydroelectric power plants located on the Sapucaí River, Dourados (7 Mw) and São Joaquim (5,2 Mw) reservoirs

Table 1. Groups of agriculture products, area and soil losses in Sapucaí Watershed

Products	Area (ha)	Erosion (t/year)
Annual crops	434,575	7,333,002
Semi-perennial crops	177,606	2,202,450
Perennial crops	60,385	54,329
Pasture	215,586	86,285
Native forest	36,845	14,738
Reforestation	21,119	19,007
Total	946,117	9,679,760

Source: CATI-IEA (1995). Soil erosion estimates were based on Belinazzi Júnior et al. (1981).

According to IPT, *Instituto de Pesquisa* (Research) *Tecnológica*, the Sapucaí Watershed is an area of critical erosion due to a predominance of silt soils. The area is close to nascent; 1/3 of the total drainage area has a high susceptibility to erosion; and the remaining area is classified as having medium susceptibility to erosion damage. (IPT, 1995). Sugar cane, coffee, soybeans, and corn are among the main agricultural crops cultivated within the Watershed.

ENVIRONMENTAL COSTS METHODOLOGY

The physical damage of productive assets caused by alterations in the quality of the environment constitute the impacts of environmental modification that, once translated into monetary terms, represent societal costs (Comune,1994). Specific and local environmental damages can be measured in terms of sacrificed production or lost revenue. (Motta, 1991). The sacrificed production method of calculating environmental impacts associates environmental change with changes in factor productivity and in the economic activity's physical end product, both of which alter production costs and benefits.

In this study, the external cost of environmental modification was the difference between the costs of electric energy production in the Sapucaí Watershed with and without the effect of sediment. Some of these effects were evaluated by assessing material damages in the watershed caused by the abrasive action of the Sapucaí River's water born solids on hydroelectric generator turbines and on other equipment in contact with the water. Whenever a river's intrinsic solids transport capacity is exceeded, the abrasive potential of its waters increases (Carvalho, 1989).

The effects of sediment and sedimentation in the river were observed through a study of the historic changes in energy generation by the Dourados and São Joaquim hydroelectric plants. The observed tendencies were then projected on the operation of eight new hydroelectric units to be constructed in that river. (CESP, 1987; CPFL, 1992). The monetary consequences of these abrasive damage were measured using the sacrificed production method and by adding costs accrued due to the actual physical damages.

The internal costs of environmental modification in the Watershed were determined by the replacement costs of soil nutrients (N, P, K, Ca, and Mg,) lost due to erosion. The replacement cost approach identifies nutrients needs as determined by type of ground cover and existing soil type. Nutrient need and fertilizer prices were used to evaluate the economic effect of soil losses. It was possible to estimate the total soil lost in tons per year due to agricultural activities for the entire Sapucaí Watershed by using the erosion rate for the cultivation of various agricultural cultures, the erosion rate for the soils they grow in, and the areas they occupy.

Price is an important variable in the calculation of environmental damages. This implies that the important prices observed in and generated by the existing market structure should be adjusted to reflect the social opportunity cost. The long run marginal cost of expansion is the social price of electric energy (Eletrobrás, 1993). The economic price for maintenance, drainage, and repair services was obtained by subtracting fringe benefits from the price of labor and then applying the calculated correction factor or adjustment coefficient (Silva Neto, 1993). The market price of the nutrients N, P, K, Ca and Mg was used to determine their replacement cost.

ANALYTICAL MODEL

The following expression estimates the internal costs:

Internal costs = $Q_n (P_n + C_a) + (P_p * Q_p)$

Where:

Q_n = lost fertilizers due to soil erosion;
P_n = price of the fertilizers;
C_a = application cost;
P_p = price of the agricultural product;
Q_p = reduction in long-term productivity due to erosion.

Application costs and productivity losses were not included in the present calculation due to lack of specific information.

The difference between energy production costs with and without the effects of the sediments in the water gives the external costs (Marques,1995):

External costs = $CE_{CA} - CE_{SA}$ or,

$$CA_A = CE_{CA} - CE_{SA}$$

$$CE_{CA} = \{ \sum_{t=1}^{m} (CM_t + RPE_t + CLD_t + CRS_t + CRE_t)(1+r)^{-t} \}\{ r(1+r)^t \cdot (1$$

$$CE_{SA} = \{ \sum_{t=1}^{m} (CM_t)(1+r)^{-t} \}\{ r(1+r)^t \cdot (1+r)^{-t} - 1\}$$

where:

CA_A = annualized external cost US$;
CE_{CA} = annualized production costs with sedimentation effects, in US$;
CE_{SA} = annualized production costs without sedimentation effects, in US$;
t = time, in years (t = 1 to 50);
r = discount rates, in % per year;
CM_t= maintenance cost, in US$, in the period t;
RPE_t = lost revenue, in US$, in the period t;
CRS_t = equipment repair cost in, in US$;
$CRS_t \neq 0$ for t = 4j, (j = 1 to 12);
CRS_t = 0 for the other cases
CLD_t = cleaning and drainage cost in US$, in the period t;

CRE_t = replacement equipment cost;
$CRE_t \neq 0$ for t = 25 years;
$CRE_t = 0$ for the other cases.

The maintenance cost (CMA_t) can be expressed as the following generic mathematical expression:

$$f(t) = x\,[y_1\,(1{,}1)^y + z_1(1{,}2)^z\,(0{,}1)^k + w_1\,(1{,}05)^w]$$

where:

f(t) defines the maintenance schedule for the useful life of the plants, for t = 1 to 50 years.

All the other parameters and power are defined as function of t :

X = energy production cost;
y_1, z_1, e w_1 = binary parameters;
y_1 = parameter of the rate (1,1);
z_1 = parameter of the rates (1,2) and (0,1);
w_1 = parameter of the rate (1,05);
y, z, k and w power potency of the rates 1.1, 1.2, 0.1 and 1.05, respectively.

The decision rules of for the condition of no-occurrence of sedimentation are the following:

y = 1 if the rest (t/6) = 0 and quotient (t/6) ≤ 3;
y = 0 otherwise;
y_1 = 0 if rest (t/6) = 0 and quotient (t/6) = 4 or t > 26;
y_1 = 1 otherwise;
z = 1 if rest (t/6) = 1 and quotient (t/6) $\geq$ 5 or
if I rest (t/6) = 0 and quotient (t/6) = 4;
z = 0 otherwise;
k = 1 if the rest (t/6) = 1 and quotient (t/6) $\geq$ 5;
k = 0 otherwise;
w = 0 and w_1 = 0 if t $\leq$ 26;
w = rest (t/26) and w_1 = quotient (t/26) otherwise.

For the conditions of high sedimentation, the rules are the following:

y = 1 if rest (t/4) = 0 and quotient (t/4) $\leq$ 4;
y = 0 otherwise;
y_1 = 0 if rest (t/4) = 0 and quotient (t/4) = 5 or t $\geq$ 23;

$y_1 = 1$ otherwise;
$z = 1$ rest $(t/4) = 3$ and quotient $(t/4) \geq 6$ or rest $(t/4) = 0$ and quotient $(t/4) = 5$;
$z = 0$ otherwise;
$k = 1$ if rest $(t/4) = 3$ and quotient $(t/4) \geq 6$;
$k = 0$ otherwise;
$w = 0$ and $w_1 = 0$ if $t \leq 23$;
$w =$ rest of $(t/23)$ and $w_1 = 1$ if $t \geq 24$.

The decision rules in the case of low sedimentation are:
$y = 1$ if rest $(t/5) = 1$ and quotient $(t/5) \leq 2$ or
rest $(t/5) = 2$ and quotient $(t/5) \leq 3$;
$y = 0$, otherwise;
$y_1 = 0$ if rest $(t/25) = 2$ and quotient $(t/5) = 4$ or $t > 25$;
$y_1 = 1$, otherwise
$z = 1$ if rest $(t/5) = 0$ and quotient $(t/5) \geq 6$,
rest $(t/5) = 2$ and quotient $(t/5) = 4$
$z = 0$ otherwise;
$k = 1$ if rest $(t/5) = 0$ and quotient $(t/5) \geq 6$;
$k = 0$ otherwise;
$w = 0$ and $w_1 = 0$ if $t \leq 25$;
$w =$ rest $(t/25)$ and $w_1 = 1$ if $26 \leq t \leq 49$;
$w = 25$ and $w_1 = 1$ if $t = 50$.

The conditions for the level of medium sedimentation are the following:
$y = 1$ if rest $(t/5)$ and quotient $(t/5) \leq 3$;
$y = 0$ otherwise;
$y_1 = 0$ if rest $(t/5) = 0$ and quotient $(t/5) = 4$ or, $t > 24$;
$y_1 = 1$ otherwise;
$z = 1$ if rest $(t/5) = 4$ and quotient $(t/5) \geq 5$ or rest $(t/5) = 0$ and quotient $(t/5) = 4$;
$z = 0$ otherwise;
$k = 1$ if I rest $(t/5) = 4$ and quotient $(t/5) \geq 5$;
$k = 0$ otherwise;
$w = 0$ and $w_1 = 0$ if $t \leq 24$;
$w =$ rest $(t/26)$ and $w_1 = 1$ if $t \geq 25$;

All the rests and quotients considered in the analytic model were the whole parts of the resulting values.

The annual lost revenue (RPE_t) measured in US$/year is defined as follows:

$RPE_t = [PE(t) \,.\, PDE] \,.\, [P_{ij}]$

Where:

RPE_t = annual revenue lost in US$;

PE(t) = adjusted price of electric energy in US$/Mw for the year t.;

PE(t) = US$ 25.20, for $1 \leq t \leq 11$; or

= US$ 33.20 , for $12 \leq t \leq 16$; or

= US$ 41.10 , for $17 \leq t \leq 50$;

PDE = 2366.6 Mw, daily production of electric energy;

Pij = matrix of sacrificed production;

i = sedimentation level (1 =low; 2 = medium and 3 = high);

j = sedimentation intensity (1 = minimum; 2 = average and 3 = maxim).

$$P_{ij} = \begin{bmatrix} 0 & 2 & 3 \\ 2 & 3 & 5 \\ 3 & 7 & 0 \end{bmatrix}$$

The cleaning and drainage cost (CLDt), in US$ was defined as:

$CLDt = (CAX_m) \,.\, [P_{ij}]$

where:

CAX_m = energy production cost,

m = 1, 2 or 3 (1 = minimum; 2 = medium and 3 = maximum).

P_{ij} = matrix of f the percentage associated to the expenses of cleaning and drainage;

i and j = level and sedimentation intensity, respectively.

m = 1, $CA\,X_m$ = US$ 31,719,282.00;

m = 2, $CA\,X_m$ = US$ 33,422,099.71;

m = 3, $CA\,X_m$ = US$ 35,962,015.00

$$P_{ij} = \begin{bmatrix} 0 & 2 & 3 \\ 3 & 5 & 6 \\ 7 & 10 & 13 \end{bmatrix}$$

The equipment replacement cost is defined as follows (CRE_t):
$CRE_t = (VEI(t)).\ [PP_{ij}]$
VEI(t) = value in US$ of the investment in turbines and other equipment,
when t = 27 VEI(t) it assumes positive value and zero if $t \neq 27$;
PP_{ij} = representative matrix of the percentage associated with the replacement value;
i and j = sedimentation level and intensity, respectively.
VEI(27) = US$ 24,331,269.00.

$$PP_{ij} = \begin{bmatrix} 7 & 10 & 15 \\ 15 & 20 & 25 \\ 35 & 25 & 20 \end{bmatrix}$$

Repairs equipment cost (CRSt) is defined as follows:
$CRS_t = (CAX_{m)}.\ [P_{ij}]$
P_{ij} = representative matrix of the percentage associated with repairs value;
i and j = sedimentation level and intensity respectively.

$$P_{ij} = \begin{bmatrix} 0 & 2 & 3 \\ 3 & 5 & 6 \\ 7 & 10 & 13 \end{bmatrix}$$

The lowest discount rate used was 3% per year, represented the actual long term rate for investments in water development projects (Schwartz & Berney, 1987). The highest rate, 9%, corresponded to the social opportunity cost for the electric sector estimated by Contador (1981). This is the rate used by BNDES in their Environmental Conservation Program and by CETESB in their Pollution Control

Program. These values are below those calculated as the Brazilian economy's social discount rate. (Motta, 1988).

RESULTS AND CONCLUSIONS

The damage caused by soil erosion is not bound by its effect on hydroelectric installations and soil nutrients. A study of these effects only quantifies partial damages. So, it is believed that the effective value of the total damages of soil erosion are more appropriately represented by the highest estimated value.

As was expected, the estimated external costs gave rise to a wide variation of inter and intra hypotheses. Given the assumed conditions, the lowest estimation of external damages was arrived at by combining low levels of river sediment with a higher discount rate. The highest cost of external damages was arrived at by combining high levels of river sediment and a the lowest discount rate (3%). Table 2 lists the external costs using discount rates of 3%, 6%, and 9% and at three levels of river solids content in the Sapucaí Watershed.

Table 2. Annual equivalent external cost in US$ 1. 000,00[1]

Disc. Rate (%)	low (US$)	medium (US$)	high (US$)
3	2,653.33	5,251.11	9,854.49
6	2,132.71	4,224.40	8,253.34
9	1,820.26	3,611.52	7,287.79

In this study, the highest off-site cost of sediment in the Sapucaí River, hypothesizing high levels of suspended solids and a 3% discount rate, was US$ 253,329,000 over 25 years (annually, US$ 9,854,490). This is approximately the construction cost of the two hydroelectric plants operating in the Watershed and 40% of the cost of the eight hydroelectric projects planned for the area.

In spite of the estimates' limitations, even partial results lend greater objectivity to the debate surrounding the cost of environmental modification. These results give a monetary figure for some of the costs of erosion. Additional studies are necessary to not only identify the monetary value of a conservation program but to identify and quantify the other societal costs of man's alteration of the natural environmental.

The determination of a discount rate frequently causes polemic. Even the defenders of the need for valuing environmental assets get involved in debates and controversies for which a definitive conclusion is not forthcoming (Pearce, 1983; Weitzman,1994; Winter-Nelson,1996). However, the estimated discount rates for each action, project, or program should be carefully adjusted to reflect the possible impact of any environmental modification. The choice of a discount rate which reflects environmental concerns has been the object of subjective interpretations and value judgments. Most of the time, the discussion of discount rate has moved to the arena of political decision-making (Winter-Nelson,1996).

The replacement cost of nutrients leached out by agricultural run-off was used in this research as the internal component of the cost of environmental modification and the ensuing erosion. This cost was as high as US$ 5,377,913 per year, and this only partially reflects the internal environmental problems caused by soil erosion. This method of estimating internal costs is highly sensitive to the market price behavior of soil nutrients. Falls or sudden increases in nutrient market price, when this price is used as base for environmental valuation, do not necessarily imply an abrupt alteration in environmental quality.

Table 3 -Economic value of the soil losses in Sapucaí Watershed

Nutrients	Soil nutrient concentration (%) *	Nutrient losses (t/year)	Fertilizer	Kg fert./ kg nutrient	Fertilizers losses (t/year)	Price of fertilizers (US$) **	Economic value of losses in US$/year
Nitrogen	0.096750	936,516.7800	urea (45% N)	2.22	2,079,067.25	215.58	4,482,053.18
Phosphorus	0.002614	25,302.8926	phosphate	5.56	140,684.083	146.17	205,637.92
Potassium	0.010058	97,359.0261	Potassium chloride	1.66	161,615.983	122.25	197,575.54
Calcium + Magnesium	0.094872	918,338.1907	dolomitic limestone	2.63	2,415,229.44	20.40	492,646.43
Soil losses in t.	9,679,760						5,377,913.07

Source: (*) Belinazzi Junior et al. 1981; (**) Anuário Estatístico do Setor de Fertilizantes, 1995.

This data includes only a few of the internal damages caused by soil erosion, other damages include: 1) the microflora and the microfauna affected by erosion; 2) diminished soil water retention capacity; 3) a large number of difficult to identify and quantify negative effects which happen simultaneously; and 4) the loss of an entire spectrum of nutrients, not included in this data, which should be restored. The layer of the soil carried off by erosion is usually the top soil layer which contains the highest concentration of nutrient organic matter and mineral elements. Each type of soil can tolerate some nutrient loss and remain at the same level of production, that loss represents its natural regenerative capacity; however, this regenerative capacity is very low in the case of the tropical soils (Bastos Filho, 1995).

Some studies have made estimates of the cost of environmental modification and/or the value of prevention/conservation measures. For example, Sorrenson & Montoya (1989), making a soil conservation study in the State of Paraná, found that costs varied from US$ 121 million to US$ 242 million annually just for replacement of the macronutrients lost due to erosion. According to the same authors, the Itaipú hydroelectric plants annually receive soil from Paranaense lands with a macronutrients value of US$ 420 million. The authors wrote that a soil conservation program for the State of Paraná would require investments on the order of US$ 19 million/year over a 20-year period.

It has been estimated that the State of São Paulo suffers annual soil nutrient erosion losses of around US$ 200 million (Instituto de Economia Agrícola, 1991). In a more recent study, Bastos Filho (1995) estimated that soil erosion caused US$ 176 million/year in nutrient losses to the State of São Paulo's agricultural, pasture, and forests lands The estimates made for the present study indicated that the internal costs generated by soil losses in the Sapucaí Watershed are about 3% of the of the state's total internal loss due to erosion.

Given that the present study is a pioneering attempt to measure the external economic effects of soil erosion in Brazil (no other estimates exist from which direct comparisons can be made), the values obtained are only indicative of the problem's order of magnitude. Nonetheless, the monetary values are very expressive; the external costs are twice the value of internal costs.

The global solution for soil and water problems is beyond the scope of the present work. Even so, from the prospective of agricultural land use, there is a need to match agricultural policy with soil conservation programs and water resources management. Any evaluation of the internal and external costs and benefits of conservation programs should incorporate environmental awareness. In this sense, a knowledge of the economic value of environmental externalities will assist public and private decision makers in their effort to preserve natural resources and improve society.

REFERENCES

ANUÁRIO ESTATÍSTICO DO SETOR DE FERTILIZANTES 1987-1996. São Paulo: Anda, 1995.

AZZONI, C.R. ; ISAI, J.Y. Estimating the costs of environmental protection in Brazil. *Ecological Economics,* v.11, n.2, p.127-133, Nov. 1994.

BASTOS FILHO, G.S. *Contabilizando a erosão do solo: Um ajuste ambiental para o produto agropecuário paulista.* Piracicaba: ESALQ-Departamento de Economia e Sociologia Rural,1995.127p. Dissertação Mestrado.

BELINAZZI JUNIOR, R., et al. A ocorrência de erosão rural no Estado de São Paulo. In: *SIMPÓSIO SOBRE O CONTROLE DA EROSÃO*, 2., 1981. São Paulo: ABGE, 1981.

CARVALHO, N. de O. *Curso sobre transporte de sedimentos e cálculo da vida útil de reservatórios.* Florianópolis: ELETROSUL, 1989. 1v.

CATI - IEA (São Paulo, SP). Levantamento da produção agrícola a nível de município, *Estado de São Paulo*, Definitiva, 1995.

CESP (São Paulo, SP). *Aproveitamento hidroelétrico do Rio Sapucaí*: estudos de viabilidade das Usinas São Domingos, São Sebastião, Monjolinho, Retiro, Anhanguera, Palmeiras, Santa Rita, Sapucaí (relatório final). São Paulo, 1987. v.1. (CESP. Pesquisa e Desenvolvimento, 35).

CLARK II, E.H.; HAVERKAMP, J.A.; CHAPMAN, W. *Eroding soils*: the off farm impacts. Washington: The Conservation Foundation, 1985. 252p.

COMUNE, A. E. Meio ambiente, economia e ecomomistas: uma breve discussão. In: MAY, P. H.; MOTTA, R.S. da, org. *Valorando a natureza:* análise econômica para o desenvolvimento sustentável. Rio de Janeiro: Campus, 1994. p.45-59.

CONTADOR, C.R. *Avaliação social de projetos.* São Paulo: Atlas, 1981. 301p.

CPFL (Campinas, SP). *Localização das usinas da CPFL - OMTT - 00-12-47.* Campinas, 1992.

CROSSON, P. Impacts of erosion on land productivity and water quality in the United States. In: EL-SWAIFY, S.A; MOLDENHAUER, W.C; LO, A. , eds. *Soil erosion and conservation.* Ankeny: Soil Conservation Society of American, 1985. p.217-236.

ELETROBRÁS (Rio de Janeiro, RJ). *Plano 2015 - Estudo da oferta e demanda:* expansão do sistema. Rio de Janeiro, 1993.

GUERRA, A. T. Dicionário Geológico-Geomorfológico, Rio de Janeiro. Fundação IBGE, 1981. 203p.

INSTITUTO DE ECONOMIA AGRÍCOLA (São Paulo, SP). Economia agrícola paulista: características e potencialidades. *Informações Econômicas*, São Paulo, v.21, p.1-201, 1991. Suplemento.

INSTITUTO DE PESQUISAS TECNOLÓGICAS (São Paulo, SP). Mapa de erosão do solo do Estado de São Paulo. Escala 1:1.000.000 1ªedição. São Paulo, 1995

MARQUES, J. F. *Efeitos da erosão do solo na geração de energia elétrica*: uma abordagem da economia ambiental. São Paulo:USP-FEA, 1995. 257p. Tese Doutorado.

MENCK, P.C.M. *Avaliação econômica do controle de erosão na microbacia do Ribeirão Iperó, em Araçoiaba da Serra, Estado de São Paulo.* Piracicaba: ESALQ, 1993. 181p. Tese Mestrado.

MONTOYA, L.J.; MASCHIO, L.M. de A.; RODIGHERI, H.R. *Impactos da atividade agrícola nos recursos naturais e sua valoração no Estado do Paraná.* [Colombo: EMBRAPA-CNPF, 1994]. 1v.

MOTTA, R.S. da. Análise de custo benefício do meio ambiente. In: MARGULIS, S., ed. *Meio ambiente:* aspectos técnicos e econômicos. Rio de Janeiro: PNUD/IPEA, 1991. p.109-134.

MULLER, A. C. *Hidrelétricas, meio ambiente e desenvolvimento*. São Paulo: Makron Books, 1996. 412p.

PEARCE, D. Ethics,irreversibility, future generations and the social rate of discount.Intern. J.*Environmental Studies*,v.21,p.67-86,1983.

RIBAUDO, M.O. *Water quality benefits from Conservation Reserve Program.* Washington, D.C.: USDA,1989, 30p. (USDA. Resources and Technology Division. Economic Research Service. Agricultural Economic Research Service. Agricultural Economic Report, 606).

SCHWARTZ,H.; BERNEY, R., ed. *Social and economic dimensions of project evaluation*. Washington:Inter-American Development Bank,1987. 338p.

SORRENSON, W.J.; MONTOYA, L.J. *Implicações econômicas da erosão do solo e do uso de algumas práticas conservacionistas no Paraná*. Londrina: IAPAR, 1989. 110p. (IAPAR. Boletim Técnico, 21).

SOUTHGATE, D.; MACKE, R. The downstream benefits of soil conservation in third world hydroeletric watersheds. *Land Economics*, v.65, n.1, p.38-48, Feb. 1989.

SILVA NETO, A.L.da Estimates of national parameters for the economic analysis of projects in Brazil. *Project Appraisal*, v.8, n.4, p.231-239, Dec. 1993.

VELOZ, J.A.; SOUTHGATE, D.D.; HITZHUSEN, F.J.; MACGREGOR, R.D. The economics of erosion control in Republican Domenican case. *Land Economics*, v.61, p.145-155, May, 1985.

WEITZMAN, M.L. On the environmental discount rate. *Journal of Environmental Economics and Management*, v.26,n.2, p.200-209, March, 1994.

WINTER-NELSON, A. Discount rates, natural resources and the measurement of aggregate economic growth in Africa. *Ecological Economics*,v.17,n.1,p.21-32,April,1996.