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Loss in Forest Resource Values Due to Agricultural Land Conversion in Brazil

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SUMMARY

LOSS IN FOREST RESOURCE VALUES DUE TO AGRICULTURAL LAND CONVERSION IN BRAZIL*

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Peter Herman May***

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ABSTRACT

This study presents a preliminary estimate of user costs of forestland conversion for agricultural purposes for the period 1970-80 in Brazil. In this initial version, only loss in potential sustainable wood output is considered. However, the analytical framework adopted here can be extended to incorporate other on-site forest products (rubber, nuts, etc.) and important off-site benefits such as biodiversity.

1. INTRODUCTION

The growing concern with the environment and the conservation of natural resources has resulted in increasing scrutiny of how valid it may be to continue treating economic growth as the yardstick for development [Goodland, et al. (1991)]. Nevertheless, the widespread dissemination of the expression "sustainable development" has not yet been matched with a consistent corresponding definition of "sustainable income", which expresses, in economic terms, the concept of growth consonant with natural resources available to fuel that growth.

In part due to the difficulty of achieving a consistent definition and methodological approach to measurement of environmental values, systems of national accounts (SNA) have only recently begun to consider means to reflect the use, depletion or degradation of natural resources. One problem is that the use of the environment is not usually valued at market prices. Since the major concern of the SNA is centered on production, activities which result in the degradation and depletion of natural resources are treated as an economic gain. To adequately reflect the alterations in society's assets that ensue from development processes, it is necessary to find means to incorporate values for these benefits or losses in natural resources within the traditional accounts.[1]

The concept of "true income" proposed by Hicks suggests a consistent approach to measure sustainable income. Hicksean true income is defined as that value which can be derived from capital resources such that, at the end of the period, the stock of capital is undiminished [El Serafy (1988)]. Sustainable income, according to Pearce and Turner (1990), is that which maintains intact the present value of the flows anticipated from a natural resource.

This study follows the approach proposed by El Serafy (1988) to identify a "user cost" that represents societal investment necessary in fixed capital to assure a sustainable income flow once forest resources are depleted. Such cost may then be considered to represent a loss that, in the SNA, may be charged against receipts from those economic activities that have resulted in forestland conversion. The resulting

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[1]See Serôa da Motta and Young (1991) for a more complete treatment of competing schools of thought on means of incorporating environmental losses in the SNA.

net value represents the sustainable income from lands converted to agricultural use.[2]

By removing forests to make way for agriculture, livestock and fuel, Brazil generates current receipts in substitution for the income that could have been generated had the forest been utilized for sustained timber and non-timber production. A part of current income is derived from commerce in wood and charcoal, and from the incorporation in agricultural products of the nutrients obtained from the ashes of forests put to the torch and from decaying vegetation. This income is already reflected in the SNA as wood products and agricultural output. Not reflected in these accounts are the unrealized returns from forest management and the indirect benefits that could have been obtained had forest cover been retained. For the purposes of this initial study, we concentrate on the benefits derived from on-site forest products, chiefly wood, leaving examination of the off-site benefits such as watershed stabilization and biodiversity for future research.

In the next section, we present the analytical framework adopted. In Section 3, we present the estimation procedures, and finally, in Section 4, the results obtained in this initial estimate of the user costs of forestland conversion in Brazil.

2. ANALYTICAL FRAMEWORK

We rely in this study upon the following analytical framework to assess the evolution of renewable resource stocks in the presence of expanding agricultural frontiers, and their contribution to economic growth. This section is based on Serôa da Motta, May and Young (1991).

Let K_{j0} constitute the physical stock of a forest resource j at a particular point in time, and let g_j be the natural growth rate of that resource in terms of incremental volume or non-wood product output. Then K_T represents the stock of j in a second moment T, in the absence of extractive activity:

$$K_T = (1 + g_j)\ K_{j0} \qquad (1)$$

[2]This method has also been applied in studies of natural capital depreciation in the United States by Daly and Cobb (1990) and in environmental accounts for Mexico prepared for the U.N. Statistical Office and the World Bank [Tongern (1991)].

Let Q_{jt} be the quantity of forest resource j that can be extracted in a period such that, at the end of the period, the forest stock is maintained at the same level as prior to extraction.

$$Q_{jt} = g_j \cdot K_{j0} \qquad (2)$$

By definition, then, if p_{jt} is the net receipt from one unit of resource j, then it should be possible to assure an infinite flow of income Y_{Ej} commensurate to a Hicksean "true income", provided extraction is maintained at a sustainable level.

$$Y_{Ej} = P_{jt} \cdot Q_{jt} \qquad (3)$$

However, activities underway in sector i result in the removal of V_{jt} ($\neq Q_{jt}$) of resource j in period t, obtaining R_{it} in net receipts. At this rate of forest conversion, the resource will be exhausted in n periods, calculated as $n = K_t/V_{jt}$.[3]

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[3]Forest stock alteration as a result of continuing extraction of V, exceeding sustainable yield, is illustrated by the following progression:

$$K_0 = K$$
$$K_1 = K(1 + g) - V$$
$$K_2 = \{K(1 + g) - V\} (1 + g) - V$$
$$K_3 = [\{K(1 + g) - V\} (1 + g)] (1 + g) - V$$

Over n periods, this expression reduces to:

$$K_n = K(1 + g)^n - V (1 + g)^{n-1} - V (1 + g)^{n-2} - - \ldots - V (1 + g)^{n-n},$$

$$K_n = K(1 + g)^n - V \sum_{t=0}^{n-1} (1 + g)^t \text{ and, finally,}$$

$$K_n = K(1 + g)^n - V (1 + g)^n - 1/g$$

As can be shown, K - V . n is a simplified version of the expression above, at the limit when the value of g tends to nill. The resource is exhausted when this progression results in $K_n = 0$. If K - V . n = 0, therefore, n = K/V.

For the purposes of this study, we have assumed that forest growth rates are extremely small relative to the rate of forest land use conversion, characterizing deforestation as an analog to mining. This assumption is supported by the literature on primary and old growth secondary tropical forests whose increment is roughly balanced by mortality. This is not the case for young secondary forest and plantation stock, which have not been included in the present analysis. Values for g are provided in Table 3.

During the process of agricultural expansion, society bears an environmental loss due to forest conversion. To compensate for the effects of forest conversion to the national economy, a portion of the receipt R_i would have to be set aside as capital stock to ensure a sustainable income flow equivalent to Y_{Ej} once the forest resource stock is exhausted. This value, U_{ij}, known as "user cost" may be identified through the procedure proposed by Serôa da Motta and Young (1991), based on El Serafy (1988), and applied below to the case of forestland conversion for agriculture.

Let $F(U_{ij})$ be the future value of user cost accumulated during n periods, at a rate of interest equivalent to the opportunity cost of capital (r):

$$F(U_{ij}) = \sum_{t=0}^{n-1} (U_{ij})\ (1+r)^t = (U_{ij})\ .\ (1+r)^n-1/r \qquad (4)$$

The present value $PV(U_{ij})$ of the accumulated capital reinvestment during this time horizon, using the social rate of time preference d as a discount rate, will be:

$$PV(U_{ij})_t = F(U_{ij})\ .\ r\ .\ 1/(1+d)^t = U_{ij}\ .\ .\ (1+r)^n-1/(1+d)^t \qquad (5)$$

This last result may then be equated to the present value of the sustainable production Y_{Ej} that would be anticipated from the forest resource in the absence of land use conversion:

$$U_{ij}\ .\ (1+r)^n-1/(1+d)^t = Y_{Ej}/(1+d)^t \qquad (6)$$

This expression simplifies finally to the following general statement of user cost:

$$U_{ij} = Y_{Ej}/(1+r)^n-1 \qquad (7)$$

In summary, the values for forest resource loss estimation are based on the following variables:

U_{ij} = user cost of forest resource j attributed to activities in sector i[4]

[4]In Brazil, agricultural, livestock and vegetal extractive activities including production of charcoal are grouped within the same account in the SNA; therefore it will not be necessary to discriminate by sector for different activities that result in forest resource loss. All user costs will be charged against agriculture sector receipts.

Y_{Ej} = value of wood and other forest products that could be removed in a sustainable fashion in a determined floristic zone

The remaining forest resource stock is estimated, squentially, assuming uniformity in volumes and species composition for areas remaining in forest at the end of each period. The period n in years to resource exhaustion is then calculated, based on the forest removal rate registered in period t, as follows:

$$n_{jt} = K_{jt}/V_{jt}$$

where:

K_{jt} = stock remaining of a given forest resource; and

V_{jt} = annual conversion of that resource for agricultural activities.

3. ESTIMATION PROCEDURES

3.1. Alteration in Forest Cover

Up to 1982, 22.5% of the national territory in Brazil had been modified by human occupation ("anthropic activity"), principally for agriculture and livestock rearing [Veloso and Goes Filho (1982)]. The data in Table 1, summarizing extant satellite imagery analysis, however, show that anthropic areas now constitute at least 32.1% of the national territory [Ibama (1991)]. This acceleration in territorial occupation has occurred in an unequal manner in different regions, owing to facility of access, variations in regional development policies and the characteristics of exploitable natural resources.

To identify changes in forest resources, information regarding land use within characteristic vegetation zones is necessary for discrete points in time. Unfortunately, there is little information of this type available for most Brazilian states, with the exception of timber inventories undertaken around 1982 in some states [IBDF (1983)], and more recent sample inventories monitoring expanded anthropic behavior in the Amazon [Tardin, et al. (1990)]. For this reason, we were obliged to have recourse to the Agricultural census data, obtained at five-year intervals since 1970, to calculate the rate of alteration in forest

TABLE 1. DEFORESTATION IN BRAZILIAN STATES

	TOTAL AREA *(1000 ha.)*	ANTHROPIC AREA *(1000 ha.)*	INVENTORY YEAR	ORIGINALLY FORESTED *(% TOTAL)*	REMAINING FOREST *(1000 ha)*
NORTE	**357,424**	**23,339**			**314,902**
Acre	15,370	1,033	(1990)	99.60%	14,275
Amapa	14,236	128	(1990)	87.47%	12,324
Amazonas	156,795	2,225	(1990)	98.32%	151,936
Para	124,683	16,214	(1990)	95.45%	102,796
Rondonia	23,838	3,350	(1990)	85.58%	17,049
Roraima	22,502	388	(1990)	75.15%	16,522
NORDESTE	**155,600**	**71,983**			**24,000**
Alagoas	2,911	2,246	(1988/89)	90.00%	373
Bahia	56,698	29,437	(1988/89)	60.00%	4,582
Ceara (inc. litig.)	14,908	12,573	(1988/89)	90.00%	844
Maranhao	32,956	3,559	(1988/89)	30.80%	6,592
Paraiba	5,396	3,777	(1988/89)	90.00%	1,079
Pernambuco	10,102	5,111	(1988/89)	90.00%	3,982
Piaui	25,127	10,912	(1988/89)	60.00%	4,165
R. Grande do Norte	5,317	3,006	(1988/89)	90.00%	1,779
Sergipe	2,186	1,364	(1988/89)	90.00%	604
CENTRO-OESTE	**188,217**	**56,216**			**61,673**
Distrito Federal	579	66	(1972)	60.00%	281
Goias (incl. TO)	61,749	27,105	(1983)	60.00%	9,944
Mato Grosso	90,142	8,362	(1990)	57.57%	43,533
Mato Grosso do Sul	35,747	20,682	(1981)	80.00%	7,915
SUDESTE	**92,427**	**73,491**			**11,114**
Espirito Santo	4,573	4,168	(1987)	100.00%	405
Minas Gerais	58,662	44,399	(1982)	90.00%	8,397
Rio de Janeiro	4,365	3,501	(1982)	95.00%	646
Sao Paulo	24,826	21,423	(1991)	93.00%	1,665
SUL	**57,532**	**48,018**			**8,111**
Parana	19,932	16,493	(1982)	100.00%	3,439
Rio Grande do Sul	28,067	25,167	(1982)	95.00%	1,497
Santa Catarina	9,532	6,358	(1982)	100.00%	3,174
BRASIL	**851,200**	**273,046**			**419,800**

Sources: IBDF (1983); IBAMA (1991); Reis (unpublished data); authors' estimates.

cover within Brazil's major floristic zones. The census data were combined with available data regarding original and altered vegetation coverage, to estimate the change in forest stocks.

The current study examines census data for the period 1970-80, and derives natural forest stock estimates from inventories reflecting 1982 forest coverage, where these exist.[5] To estimate annual loss in forest cover and remaining stock in a given year for each state, the following formula was applied:

$$K_{jt+1} = K_{jt} - [(A_{jt+1} - F_{jt+1}) - (A_{jt} - F_{jt})] \qquad (8)$$

where:

K_{jt} = forest stock in state j in period t (area under forest vegetation)

A_t = area in agricultural establishments

F_t = forested areas within agricultural establishments (not including fallow)

This formulation assumes that areas opened to agricultural production in a given period were previously covered in forests, which is not always the case. Adjustments were made based on average forest cover characteristics. The change in forest cover ($K_{t+1} - K_t$) was estimated in five-year intervals from the agricultural census, and then annualized. Should there

[5]For Amazon states, Maranhão and Mato Grosso, data on original natural forest cover as a proportion of total state area (Eustáquio Reis, pers. comm.) was combined with 1990 satellite imagery results [Ibama (1991)] to provide an estimate of remaining stock in inventory years (see Table 1). In the Center-West, original cover estimates for Goiás and the Federal District were estimated at 60% based on the figure for Mato Grosso. For Northeast states, original cover estimates were based on the 1982 vegetation map [Veloso and Goes Filho (1982)], using the **caatinga** category as a basis for regional estimates, originally covering an average of 90% of state territories. In Piauí and Bahia, this value was reduced to 60%, reflecting the importance of **cerrado** landscapes. For the Center-South and South, forest cover information by state for different vegetation types was available from 1982 forest inventories, from which secondary growth categories (e.g., **capoeira**) were removed to avoid double-counting of lands converted to agriculture in prior years [IBDF (1983)].

be evidence of exponential change in forest cover in a given state, an annual depletion rate was applied. For example, Table 2 shows that, in the North region, the area cleared for agriculture increased from 9.3 to 11.1 million ha. between 1970 and 1975, a difference of 0.4 million ha. each year. In the period 1975-80, however, agricultural expansion led to clearing of an additional 0.9 million ha. annually, demonstrating an exponential rather than linear growth pattern during the decade. For those states which demonstrated this pattern, therefore, an annual clearing growth rate was estimated for each five year period, leading to increasing annual estimates for the intervening years. Finally, the annual estimates were smoothed using three-year moving averages.

The estimates of deforested area within agricultural establishments generated by this procedure (Table 2) enable approximation, both forward and backward from the data points available, of annual loss in forest cover related to agricultural expansion and, simultaneously, of years to resource depletion. In those states where forest cover alteration has been studied using satellite imagery, the forest conversion rates derived from the above procedure were verified. In general, the census data proved suitable predictors of forest removal, being consistent with satellite imagery data for most states. For example, the 1980 census data show that agricultural establishments had cleared 60.7 million ha. in the Northeast, increasing at a rate of approximately 1 million ha. each year. The inventories reported by Ibama (1991) showed that by 1989/90, anthropic area in the Northeast had reached 72 million ha., an area similar to that which would have been predicted by the census data.

Adjustments were necessary in the **cerrado** (Center-West) region and in Maranhão where, perhaps due to the complexity of identifying land clearing in the open savanna from satellite images, the census data were inconsistent with available inventories. For example, the census data showed agricultural expansion had led to clearing of 21.2 million ha. in Mato Grosso by 1980 (Table 2), but the anthropic area registered in 1990 was only 8.4 million ha. (Table 1). To compensate for this discrepancy, the proportion of area originally under forest based on vegetation mapping was applied to the census data, to provide more reliable estimates of forest depletion in census years.

TABLE 2. AGRICULTURAL EXPANSION IN BRAZILIAN STATES: 1970-80

	1970 CENSUS	1975 CENSUS	1980 CENSUS
	-----	(1000 ha)	-----
NORTE	**9,301**	**11,111**	**15,512**
Acre	208	244	570
Amapa	402	536	469
Amazonas	1,005	1,685	1,697
Para	5,857	6,571	9,536
Rondonia	561	530	1,394
Roraima	1,268	1,545	1,846
NORDESTE	**51,730**	**54,724**	**60,732**
Alagoas	1,846	1,989	2,120
Bahia	16,660	19,311	23,276
Ceara (inc. litig.)	8,876	8,427	8,435
Maranhao	2,730	2,891	3,601
Paraiba	4,081	4,005	4,106
Pernambuco	5,483	5,669	5,193
Piaui	6,922	7,791	9,093
R. Grande do Norte	3,600	3,033	3,258
Sergipe	1,532	1,608	1,650
CENTRO-OESTE	**68,155**	**76,512**	**88,944**
Distrito Federal	156	170	270
Goias (incl. TO)	30,872	36,758	40,964
Mato Grosso	14,291	14,848	21,175
Mato Grosso do Sul	22,837	24,736	26,535
SUDESTE	**62,848**	**66,007**	**65,501**
Espirito Santo	3,104	3,399	3,360
Minas Gerais	38,327	40,575	40,751
Rio de Janeiro	2,850	2,958	2,760
Sao Paulo	18,567	19,075	18,630
SUL	**39,743**	**41,180**	**42,912**
Parana	12,260	13,676	14,407
Rio Grande do Sul	22,081	22,061	22,439
Santa Catarina	5,402	5,443	6,066
BRASIL	**231,777**	**249,534**	**273,601**

Source: IBGE (1970); (1975); (1980).

3.2. Forest Resource Characteristics and Sustainable Production

Different forest formations existent in different parts of Brazil are here characterized so as to be able to estimate the loss in terms of volume and value of forest production foregone due to agricultural conversion. Lands converted for agricultural purposes in a given floristic region are, for reasons of simplification, assumed to have the same user cost per unit area regardless their other characteristics (e.g., species composition, soil or slope suitability, microclimate, etc.). The average productivity (annual wood increment per ha.) of principal timber resources in each major phytogeographic zone constitutes the physical basis for user cost estimation.

Brazil has nine major phytogeographic zones, and three diffuse areas of transition and refuge characterized for the purposes of vegetation mapping by IBGE, based on data derived from the Radambrasil project [Brazil (1973-82)]. These nine principal mapping units have broadly similar characteristics as regards floristic composition, standing wood volume and vegetation growth rates, owing to similar climatic and soil associations within major forest formations.

To determine in which floristic zone a given state should be classified, political boundaries were superimposed on a 1:5 million scale vegetation map of Brazil. If a state is divided between two or more floristic zones, it is classified in that zone which represents over 50% of its area. In this way, all the area within a given state converted to agriculture is classified in the same floristic zone. Table 3 provides an initial classification of Brazilian states by predominant vegetation type. Further phases of this research will involve disaggregation to the substate level in order to more precisely estimate depletion of specific vegetation resources.

In this exploratory study, therefore, no attempt has been made beyond the classification of states within broad vegetation groups to differentiate commercially important forest stocks. The time horizon to depletion (n) of a given type of vegetation is here identified as a function of the annual rate of forest depletion (V_t), and estimated initial stock (K_t) for each state.

To identify the volume of forest products (Q_{jt}) that could have been harvested sustainably on an annual basis from those areas subject to agricultural conversion, we reviewed studies of natural forest management and consulted with regional forestry

TABLE 3. REGIONAL VEGETATION CHARACTERISTICS IN BRAZIL

	PREDOMINANT FOREST TYPE	ANNUAL INCREMENT (m3/ha)	TOTAL VOLUME (m3/ha)
NORTE			
Acre	ombrofila aberta	0.48	70.0
Amapa	ombrofila densa	0.60	90.0
Amazonas	ombrofila densa	0.60	90.0
Para	ombrofila densa/aberta (tensao)	0.48	80.0
Rondonia	ombrofila aberta	0.48	70.0
Roraima	ombrofila densa	0.60	90.0
NORDESTE			
Alagoas	ombrofila aberta/caatinga (tensao)	0.48	40.0
Bahia	caatinga/cerrado	0.20	37.5
Ceara (inc. litig.)	caatinga	0.20	37.5
Maranhao	ombrofila densa (pre-amazonica)	0.50	60.0
Paraiba	caatinga	0.20	37.5
Pernambuco	caatinga	0.20	37.5
Piaui	caatinga/cerrado (tensao)	0.20	37.5
R. Grande do Norte	caatinga	0.20	37.5
Sergipe	caatinga/tensao	0.20	37.5
CENTRO-OESTE			
Distrito Federal	cerrado	0.20	45.5
Goias (incl. TO)	cerrado	0.20	45.5
Mato Grosso	cerrado/ombrofila aberta (tensao)	0.48	61.0
Mato Grosso do Sul	cerrado	0.20	45.5
SUDESTE			
Espirito Santo	mata atlantica (tabuleiro)	0.64	67.0
Minas Gerais	cerrado/estac. semidecidual (tensao)	0.20	45.5
Rio de Janeiro	mata atlantica	0.64	67.0
Sao Paulo	mata atlantica/estac. semidecidual	0.50	67.0
SUL			
Parana	ombrofila mista/estac. semidecid.	0.50	67.0
Rio Grande do Sul	campos gerais/decidua estacional	0.50	67.0
Santa Catarina	ombrofila mista/mata atlantica	0.64	67.0

Sources: FAO (1985); Veloso & Goes (1982); R. Jesus de Moraes (pers. com.); E. F. Durso (pers. com.).

specialists regarding the productivity of vegetation formations present in the major floristic zones of Brazil (see acknowledgements in footnote 2). The annual average permissible cut in a sustainable management system is here assumed to be equivalent to the average annual natural increment in merchantable wood volume in each floristic zone. This volume, described as g_j in equation (1) above, is that increment necessary to maintain forest volume in equilibrium under climax conditions. It is assumed for the purposes of this study that sustained forest management would imply removal of only this increment. We recognize that this is a conservative estimate, since managed forests can be assumed to produce volumes well in excess of the natural increment. The annual wood increment figures adopted for this preliminary study are provided in Table 3, for each state, showing their assumed correspondence with major vegetation groups.

3.3. Resource Valuation

For the calculation of the annual value of sustainable wood production lost to society through land conversion (Y_{Ejt}), it is desirable to apply the rent value (p_{jt}) of timber resources at the point of extraction (stumpage). This value can be approximated by deducting the average costs of extraction and transport from international market prices per unit output.

The average FOB prices of processed wood products in tons exported in US dollars were obtained from Cacex series for the years under consideration. These prices were adjusted to 1980 values by the U.S. Consumer Price Index for each of the ten years 1971-80. Information regarding extraction and transport costs have here been derived from input-output tables for the Brazilian economy prepared for the reference year 1975 [IBGE (1979)]. According to this source, average rent to wood product resource owners was on the order of 75% of gross FOB sales value.[6] This proportion was applied uniformly over the decade in question, in the absence of input-output coefficients for other years. A standard conversion rate of 0.85 m3 per ton was used to value the wood product loss due to deforestation. To summarize, the annual estimate of Y_{Ej} is derived for each state by the following formula:

$$Y_{Ejt} = [(K_{jt+1} - K_{jt}) . g_j] \ . \ 0.85p_{jt} \qquad (9)$$

[6]Although marketing margins make up the bulk of estimated rents, and resource owners are under-compensated for timber value, these rents are used to reflect the value to society of standing forests.

The stumpage values and corresponding macroregional sustainable wood production estimates derived using the above formula are presented in Table 4 for the decade in question.

3.4. Agricultural Product and user Cost Estimation

Based on the above described procedures for valuation of **sustainable wood production foregone** (Y_{Ejt}), annual user cost values (U_{ij}) were derived for each Brazilian macroregion, at discount rates of 5% and 15%, applying equation (7). Table 5 provides a summary of the annual depletion horizons (n) and user cost estimates.

To determine the sustainable income from agricultural activities that have supplanted forest land uses, we then subtracted the respective user cost values from estimated annual gross agricultural/livestock product (R_t) derived from the incremental agricultural lands. The latter values were based on agricultural sector product data for 1970, 1975 and 1980 [IBGE (1987)]. The state agricultural product per hectare in these years was estimated by first dividing gross state agricultural product by total land in agriculture less forestland -- $A_t - F_t$, in equation (8). These per-hectare product values, presented in Table 6 for the Brazilian states, were then multiplied by our annual deforestation estimates to generate values for incremental agricultural product by state. These data were then adjusted using three-year moving averages, and converted to 1980 US dollars.

This procedure provides an estimate for sustainable income (gross agricultural product net of forest user costs, or $R_t - U_{ij}$). Gross product, user cost and sustainable income values are plotted in Figure 1, illustrating the substantial inverse effect of market interest rates on sustainable use of renewable resources. Before discussing the results, the following factors should be considered in their evaluation and also for further research to refine this estimation:

a) Prices (p_{jt}) should reflect elasticity of international wood products demand, and the changing product mix of Brazilian wood product exports, since the entry in the market of significant volumes of wood otherwise lost to agriculture might have provoked a drop in FOB prices. Wood product net receipts (Y_{Ejt}), should be refined so as to reflect variations in production cost composition over the period under consideration.

TABLE 4. SUSTAINABLE WOOD PRODUCTION FOREGONE IN BRAZIL: 1971-80

	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
	Stumpage Value (in 1980 US$/ton)									
	$195.40	$214.46	$236.44	$339.15	$383.14	$343.17	$333.37	$318.71	$343.96	$325.31
	Values for Yij - Sustainable Wood Production Foregone (US$000)									
NORTE	$31,325	$34,640	$38,771	$56,467	$80,602	$88,805	$105,278	$108,769	$128,399	$126,829
NORDESTE	$32,086	$35,711	$40,476	$59,688	$74,751	$73,836	$78,744	$77,812	$86,805	$83,452
CTR-OESTE	$60,804	$66,780	$73,729	$105,905	$163,065	$188,658	$228,531	$229,758	$261,023	$253,189
SUDESTE	$21,474	$23,568	$25,984	$37,271	$35,112	$25,185	$18,380	$17,572	$18,964	$17,936
SUL	$24,374	$26,750	$29,493	$42,304	$52,554	$51,337	$54,014	$51,639	$55,729	$52,708
BRASIL	$170,063	$187,449	$208,452	$301,635	$406,084	$427,820	$484,946	$485,549	$550,920	$534,113

TABLE 5. DEPLETION HORIZONS AND ESTIMATED USER COST VALUES

	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Values for "n" -- Years to Resource Depletion										
NORTE	980	964	948	932	916	469	444	405	369	335
NORDESTE	54	51	49	46	44	38	36	34	32	30
CTR-OESTE	60	59	57	56	55	40	37	35	33	31
SUDESTE	38	37	36	35	34	48	47	46	45	44
SUL	41	40	39	38	37	30	29	28	27	26
User Cost at 5% Discount Rate in US$000										
NORTE	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
NORDESTE	$2,517	$3,199	$4,130	$6,923	$9,837	$13,792	$16,682	$18,675	$23,581	$25,647
CTR-OESTE	$3,514	$4,074	$4,749	$7,203	$11,714	$31,816	$44,033	$50,623	$65,828	$73,164
SUDESTE	$3,933	$4,574	$5,347	$8,136	$8,137	$2,612	$2,012	$2,031	$2,315	$2,313
SUL	$3,775	$4,385	$5,118	$7,775	$10,236	$15,056	$16,881	$17,215	$19,838	$20,057
BRASIL	$13,739	$16,231	$19,343	$30,037	$39,924	$63,276	$79,607	$88,543	$111,562	$121,181
User Cost at 15% Discount Rate in US$000										
NORTE	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
NORDESTE	$18	$28	$44	$91	$158	$372	$536	$711	$1,056	$1,340
CTR-OESTE	$15	$19	$24	$40	$71	$740	$1,240	$1,718	$2,676	$3,542
SUDESTE	$103	$130	$165	$273	$296	$29	$24	$27	$33	$36
SUL	$77	$98	$124	$205	$293	$743	$900	$992	$1,235	$1,348
BRASIL	$213	$274	$357	$608	$817	$1,883	$2,701	$3,448	$5,000	$6,266

b) Average volume to weight conversion rates for the principal wood species in each region should be applied, as should better estimates for annual wood increment (g_j), with a focus on commercial species.

c) Substate political units should be superimposed on vegetation maps for the entire nation, to more accurately characterize the rate of deforestation within major floristic zones, and therefore to generate a more precise value of n.

4. RESULTS AND DISCUSSION

The results in Figure 1 indicate a considerable economic loss due to deforestation, even when only the value of wood is deducted from the estimated agricultural product derived from this converted land. If the user costs for prior land conversion had been taken into account in the year deforestation occurred, the rate of agricultural growth would have been reduced commensurately. During the first part of the decade in question, land conversion was comparatively slow. The rate of deforestation from 1975 to 1980 increased dramatically, responding to credit availability and other macroeconomic factors. The growing social cost of forest conversion is particularly evident in Figure 1 at the 5% discount rate, which results in an estimated deduction of 36%, or US$ 121 million from the gross output from converted land in 1980 alone (Table 7). On the other hand, the downward effect on user costs at higher discount rates is significant, demonstrating the importance of social time preference on environmental values. At a rate of 15%, the results for 1980 in Table 5 show that US$ 6 million must be deducted from gross agricultural product to account for environmental losses due to forest conversion.

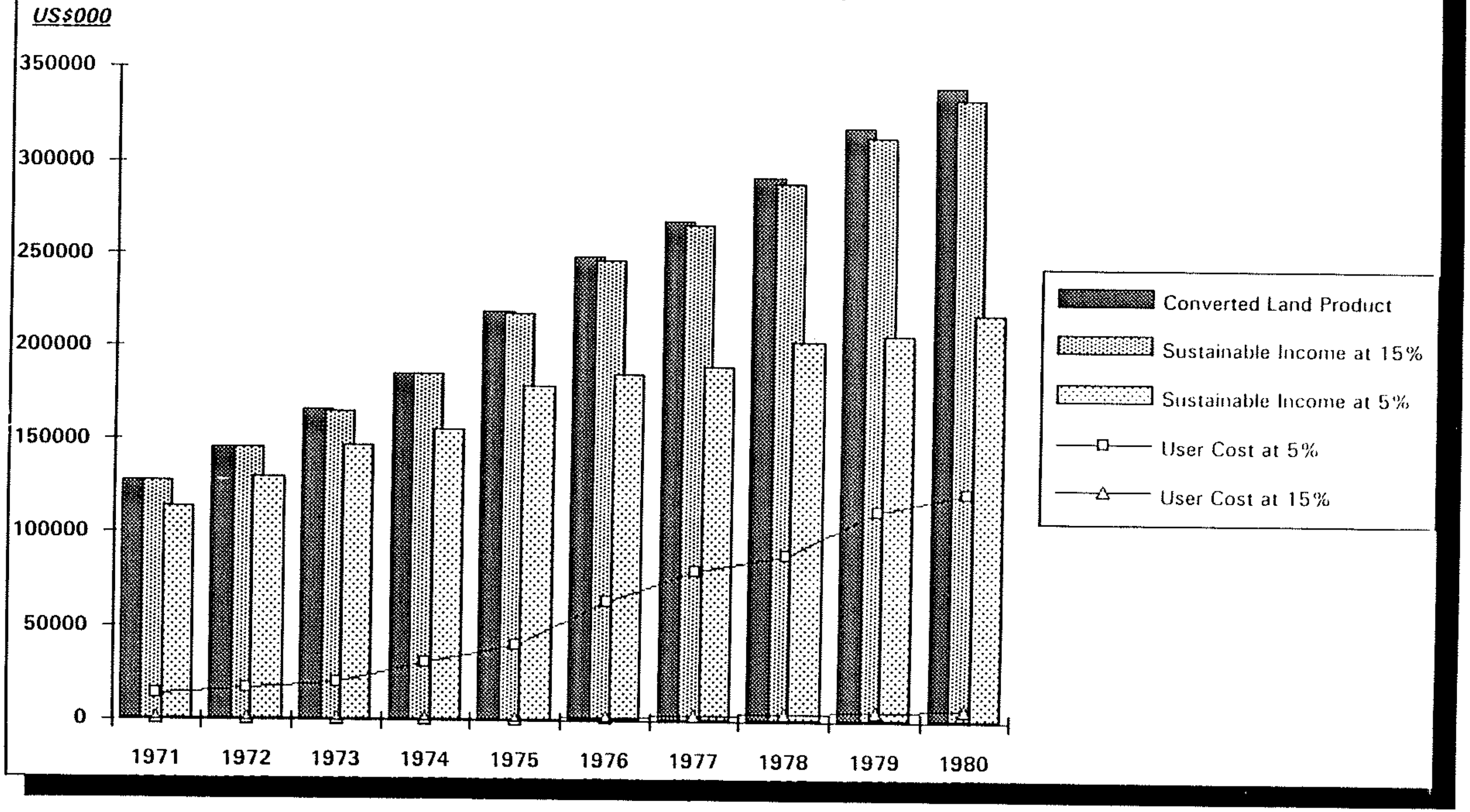
Despite recent concerns, the large expanse of Amazon rainforest that remains after clearing in the 1970s effectively eliminates the value of this loss from the analysis even at a relatively low discount rate of 5%. However, if the rate of deforestation in the Amazon continues to demonstrate exponential growth patterns, it is likely that agricultural expansion will generate significant user costs in the 1980s. Although in the period analyzed, the rate of deforestation of the Amazon forest was not yet alarming, in other floristic zones the process of land conversion had already reached an impressive pace. Based on our estimates for

TABLE 6. VALUE OF AGRICULTURAL PRODUCT IN BRAZILIAN STATES: 1970-80

	AGRICULTURAL PRODUCT		
	1970	1975	1980
	1980 Cr$ per hectare		
NORTE	**2,492**	**3,188**	**3,939**
Acre	11,462	9,279	6,241
Amapa	1,035	1,358	2,844
Amazonas	7,425	5,812	6,797
Para	1,944	2,927	3,951
Rondonia	1,817	4,781	4,342
Roraima	397	563	512
NORDESTE	**2,302**	**3,470**	**3,954**
Alagoas	4,791	6,937	8.865
Bahia	2,406	3,209	3,650
Ceara (inc. litig.)	1,402	2,585	3,378
Maranhao	5,931	8,678	8,963
Paraiba	2,129	3,916	3,400
Pernambuco	3,427	4,788	6,470
Piaui	764	1,155	1,137
R. Grande do Norte	1,269	3,234	2,947
Sergipe	2,736	3,492	4,935
CENTRO-OESTE	**621**	**1,036**	**1,574**
Distrito Federal	1,438	3,014	3,443
Goias (incl. TO)	776	1,267	1,548
Mato Grosso	423	589	827
Mato Grosso do Sul	529	947	2,190
SUDESTE	**3,108**	**4,660**	**6,524**
Espirito Santo	3,583	4,960	7,722
Minas Gerais	1,765	2,905	4,943
Rio de Janeiro	4,854	7,254	8,837
Sao Paulo	5,533	7,935	9,424
SUL	**4,799**	**8,413**	**8,472**
Parana	5,639	11,847	9,993
Rio Grande do Sul	4,117	6,194	6,898
Santa Catarina	5,681	8,777	10,681
BRASIL	**2,462**	**3,841**	**4,503**

Source: IBGE (1987)

FIGURE 1. **Agricultural Product and Deforestation User Cost**



n, the period to resource exhaustion (Table 5), at the rate of depletion underway in the South, Northeast and Center-West in 1980, forest cover in these macroregions would be obliterated, respectively, in the years 2006, 2010 and 2011. In the Southeast, a stabilization of depletion rates by the end of the 1970s resulted in an estimate for forest exhaustion in the year 2024, but this conceals the fact that most reserves had already been removed by 1980. These regions should receive greater attention owing to imminent annihilation of forest resources, whose value is commensurately more significant to the analysis of sustainable income.

If the user cost results are compared to total Brazilian agricultural product (Table 7), on the other hand, they could be considered quite minor, ranging from 0.1 to 0.5% during the 1970s. Such results, however, confirm the conventional wisdom that wood marketing does not generate enough net receipts to stimulate natural forest exploitation based on sustained yield harvesting. Therefore, it is imperative to find ways to ensure higher market values for other forest products if conservation is to become a viable option for forest land use.

The results presented here suggest another important issue related to environmental accounting of forest uses.Previous attempts to estimate deforestation costs undertaken by Repetto et al. for Indonesia (1989) and Costa Rica (1991) based their accounts on the concept of depreciation. In these studies, the authors assume that net forest depreciation is equivalent to the entire net receipts that could be derived from marketing of wood removed through deforestation and timber extraction. The physical accounts were adjusted by additions to forest stock arising from natural growth and reforestation, and losses from fire, disease and pests. In this approach, the entire physical output of converted land is multiplied by the unit net receipt (rent) of wood sale. If such a procedure were adopted here, even assuming that only 25% of the value of all wood available from converted forestland in Brazil (see Table 3 for total volume estimates employed), could be treated as a net loss, the results would be considerably different from those estimated by the user cost concept. As can be seen in Table 7, a much larger value - in some years nearly equivalent to the entire agricultural product of Brazil - would then be considered as environmental loss. The depreciation approach thus suggests that the nation would have been economically better off exploiting most of its forests for sustained yield than in expanding its agricultural frontiers. While we do not necessarily disagree with

TABLE 7. USER COST VERSUS DEPRECIATION APPROACH

	(A) User Cost at 5% Discount (US$000)	(B) Converted Land Product (US$000)	(A)/(B)
1971	$13,739	$127,690	11%
1972	$16,231	$146,192	11%
1973	$19,343	$165,779	12%
1974	$30,037	$185,771	16%
1975	$39,924	$219,081	18%
1976	$63,276	$248,942	25%
1977	$79,607	$268,686	30%
1978	$88,543	$292,188	30%
1979	$111,562	$318,223	35%
1980	$121,181	$339,748	36%
	(C) Depreciation Approach (US$000)	(D) National Agric. Product (US$000)	(C)/(D)
1971	$7,540,945	$16,351,655	46%
1972	$8,310,812	$17,027,653	49%
1973	$9,581,031	$17,041,286	54%
1974	$13,367,031	$17,265,740	77%
1975	$17,120,170	$18,493,724	93%
1976	$17,330,397	$18,917,475	92%
1977	$19,021,694	$21,306,342	89%
1978	$18,965,096	$20,723,998	92%
1979	$21,431,200	$21,762,047	98%
1980	$20,737,066	$24,059,754	86%

this conclusion, we feel it is not desirable to apply the depreciation approach to estimate the environmental accounts.

It could be argued that the depreciation approach is more valid for Indonesia, where most deforestation is due to wood extraction, than in Brazil, where deforestation is the result of agricultural expansion. Nevertheless, even if Brazil were to be similar in this sense to Indonesia, only part of the net receipt (a proxy of rent) should be discounted from agricultural output value as depreciation rather than the entire net receipt applied in the depreciation approach. As demonstrated earlier in this paper, that part - user cost - should be such that when all remaining forest is converted, the future value of this accumulated user cost would be enough to generate a perpetual income stream equivalent to the agricultural output value minus user cost, which would be the sustainable income resultant from forest use for timber extraction. That is, part of the rent appropriated from forest use should be set aside each year during the process of exploitation so that, at the time of resource depletion, its accumulated value assures an income flow that is constant and sustainable.

The income generated from wood marketing must be one that allows future generations to perceive the same income level as the present generation. It is assumed that forests as assets can be replaced by other types of assets [see Serôa da Motta and Young (1991)], i.e., material capital in other economic sectors with the same economic return. However, there may be benefits to be derived from the retention of standing forests by future generations that cannot be substituted by investments in other sectors equivalent only to the present value of sustainable on-site forest products. Elimination of off-site uses of forests such as biodiversity and global climate stabilization should also be considered as losses in future income from converted areas and, therefore, will increase the user cost and decrease the current value of income arising from deforestation. However, until global society begins not only to show "willingness to pay" by protesting deforestation, but also to actually pay to protect these other forest uses, which benefit the world at large and not only Brazil, the sustainable income of forests, in terms of Brazilian growth, can only reasonably reflect the current commercial values arising from marketed products such as wood, as estimated here.

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