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ANALYSIS

The total economic value of Amazonian deforestation, 1978–1993

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Abstract

National income accounting has been criticized because of its failure to encompass the notion of sustainability. Several studies address this problem through 'green' income accounting — i.e. by adjusting conventionally measured GDP for reduction in a given country's 'stock' of natural resources. These studies generally base value on the unit net price of the resource. Other studies go beyond net price, emphasizing a natural resource's total economic value (TEV) — that is, its non-marketable as well as its marketable values. This paper combines the green income accounting and TEV approaches and applies the new framework to Brazil in order to assess the foregone economic benefits resulting from Amazonian deforestation. The results lend support to calls for greater policy emphasis on conservation of unique and irreplaceable ecosystems.

Keywords: Brazil; Income accounting; Ecosystem valuation; Total economic value

1. Introduction

World Resources Institute (WRI) studies on Indonesia (Repetto et al., 1989) and Costa Rica (Solórzano et al., 1991) note that national income, or GDP, is misspecified in the United Nations system of national accounts (SNA), and argue that this misspecification may encourage economic growth that is unsustainable. Since the SNA treats 'man-made' capital (e.g. machines, factories) as a form of wealth in a nation's income accounts, these reports contend that it should also do so for natural resources. Yet, although depreciation of man-made capital counts against gross income in the national accounts, an analogous adjustment for 'natural capital' is absent from the SNA. The WRI reports seek to rectify this inconsistency by estimating annual losses in the natural resource accounts for their respective countries, and deducting these from gross income.

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These studies, like subsequent ones (see, e.g. Bartelmus et al., 1992; Cruz and Repetto, 1992; Margulis, 1992), base the value of the depleted resources on their associated potential revenue streams, assuming the overall 'stock' of natural resources to be diminishing over time. In other words, they implicitly embrace 'development' of natural areas over conservation. Other studies (e.g. Pearce, 1991; Kramer et al., 1992; Adger et al., 1995; Kumari, 1995), in contrast, take conservation benefits into account in assessing the total economic value (rather than merely the marketable value) of particular resources. These latter authors, however, do not apply these estimates to the revised income accounting framework discussed above.

This study is a synthesis of the two approaches. Rather than adjusting national income for the 'natural capital' loss evaluated, assuming eventual exhaustion of natural resource stocks, it deducts from national income values associated with conservation benefits — i.e. the sustainable portion of marketable benefits and all non-marketable benefits. Additionally, the study introduces a method with which to adjust calculated value for increased (or decreased) resource scarcity over time. The framework is applied to Brazil, a country that has suffered considerable deforestation in its Amazon basin from 1978 to 1993. I hypothesize that income adjustments based on the Brazilian Amazon's conservation benefits will, relative to GDP, exceed those based on the 'development' benefits estimated in earlier studies.

The remainder of this paper proceeds as follows. The next section reviews in greater detail the original premises of the natural resource accounting studies. Section 3 discusses total economic value and presents unit value estimates for the Amazon forest. The results are presented in Section 4, showing both the extent of physical deforestation (by state and in aggregate) and the associated damages. Finally, Section 5 presents the conclusion and some parting thoughts.

2. Income and natural resource accounting: some problems

As noted by Repetto et al. (1989), it is difficult to overstate the political and economic impact of the national income accounts. The GDP growth rate is the primary standard of economic progress for all countries, but especially for lesser-developed countries (LDCs). Yet GDP may represent unsustainable income. Not only does pursuit of GDP growth by an LDC offer no protection for its stock of natural resources, such a policy may be in conflict with its conservation.

Income, at a fundamental definitional level, encompasses sustainability. As noted by Hicks (1946), 'Income is the maximum value that a person can consume during a time period and still expect to be as well off at the end of the period as at the beginning'. In other words, cash flows that make one worse off over time ought to count as capital consumption, not income. The SNA notes this distinction in the case of 'man-made' capital (hereafter K_M), regarding its consumption as depreciation.

Hicks, of course, does not mention natural resources. Can they also be classified as capital? Although biologists or ethicists, among others, might object, we can certainly think of them as such. Literally, capital means wealth. Insofar as natural resources possess some economic value (an incontestable point), they are a form of capital by definition, despite not being produced, as is K_M, by human hand or machine. Hence, sustainable income should be defined as the maximum flow that will still allow the aggregate value of K_M and 'natural capital' (K_N) stocks to be preserved.

The WRI studies on Indonesia and Costa Rica calculate the losses associated with the depletion of three types of K_N stocks, and deduct these from GDP for a series of years in the 1970s and 1980s.[1] For the most part, they base their value estimates on the world market price (minus extraction cost) of the resource in question. Both studies report considerable losses, and the Indonesia study finds growth in 'green GDP' for the studied period to

[1] Specifically, the Indonesia study considered timber, petroleum, and soil, and spanned the 1971–1984 period, while the Costa Rica study estimated losses occurring in the timber, soil, and fishery sectors, and surveyed the 20-year period from 1970 to 1989.

be significantly less than conventionally measured GDP growth. Given the substantial resource depletion suffered by both countries, the findings of these reports support the general claim that GDP growth might, if K_N stocks are eventually exhausted, be unsustainable.

Without a doubt, these studies make an important contribution to the environmental and development economics literature. However, the use of price as a proxy for value is open to question. Under complete markets and perfect competition, such an approach would not be unreasonable. In such a case, we would expect growing scarcity of a particular resource to be signaled by a rising price. Moreover, resource benefits that cannot be capitalized in the market — e.g. the potential social gain associated with a future discovery of a use of a particular plant — would, assuming perfect information, also be reflected in the price of the resource.

But in the real world, price is no safeguard against scarcity. If, for example, a forest is harvested at an unsustainable rate, more wood products are supplied to the world market than under a more prudent regime. The greater supply drives down the market price. Thus, basing the value of resources such as wood on the corresponding market price perversely results in artificially low resource values, which may in turn imply less incentive to preserve them for future use.

Additionally, the world market price of a resource is based on global supply and demand, which reflect the expected value-added of the resource as a raw material in the production of other commodities. But there are 'missing markets' for an abundance of other types of values that cannot be realized in the traditional global market. Due to the admittedly crude means of estimating some of these values, many economists are unwilling to consider them. Yet failing to do so introduces a severe anti-conservation bias into the analysis, as noted by Pearce (1991):

> Typically, development benefits can be fairly readily calculated because there are attendant cash flows…Conservation benefits, on the other hand, are a mix of associated cash flows and 'non-market' benefits. Components with associated cash flows are made to appear more 'real' than those without such cash flows…[D]ecisions are likely to be biased in favor of the development option because conservation benefits are not readily calculable…Unless incentives are devised whereby the non-market benefits are 'internalized'…conservation benefits will automatically be downgraded…This 'asymmetry of values' imparts a considerable bias in favor of the development option.

Two observations are in order. First, many 'non-market' benefits cannot be provided by K_M. In other words, it is imprecise to think of K_N and K_M as mere substitutes. Widespread belief that human technology will continually develop alternatives that reduce our dependence on natural resources no doubt contributes to their underpricing. The assertion by the WRI reports that sustainability requires preservation of total (i.e. man-made plus natural) capital implies that they are substitutable because it allows K_N to be exhausted as long as the reduction is offset by increases in K_M. Since natural resources contribute benefits not provided by K_M — and vice versa — it is more accurate to regard the two forms of capital as complements. Many commodities (e.g. automobiles, furniture) would not be producible without raw materials. If K_N and K_M were truly substitutes, we would not require K_M in the first place. Most important, no amount or type of K_M can fully replace the integrity of ecosystems damaged through excessive exploitation of natural resources. Therefore, a more prudent approach to sustainability would also require preservation of K_N stock.

Second, following from this, a reasonable means of approximating the 'non-market' benefits must be developed. While not pertinent to some types of resources — like gold or petroleum for which 'market' benefits account for most if not all of total value — these benefits might constitute a significant portion, if not a majority, of total value for other resources. Tropical forests, for example, may be among the areas containing the greatest wealth of 'non-market' benefits.

Of the world's tropical forests, the Brazilian Amazon may be among the most valuable. Accounting for about 45% of Brazil's area, many believe its vegetation plays an important role in regulating global temperatures. The Amazon is also home to an enormous and still unmeasured biological diversity, accounting for up to a tenth of all the Earth's plant and animal species. Perhaps not as well known, the region contains about two-thirds of the earth's surface fresh water (Pearce et al., 1990).

Economic development and deforestation have threatened the Amazon in recent decades, particularly following the late 1970s. The remainder of this paper estimates the 'unit value' of Amazonian forest, and assesses the overall loss Brazil has suffered from 1978 to 1993 as a result of deforestation.

3. Amazonian total economic value

3.1. The concept

The total economic value (TEV) of a natural resource is the sum of its direct, indirect, option, and existence values (see, among others, Pearce, 1991; Groombridge, 1992). Direct value is related to the direct use of the resource. In the case of tropical forests like the Amazon, this includes, in addition to commercial timber, materials like resins, latex, and dyes, as well as food such as fruit and nuts. Additionally, potential tourism revenues (recreational values) contribute direct use value.[2]

Indirect use value is associated with benefits that individuals experience indirectly, or as a consequence of the primary function of a given resource. For example, the forest's ability to sequester carbon from the atmosphere yields positive externalities by helping to regulate the global climate. As another example, forests are an effective defense against soil erosion, consequences of which include reduced soil fertility and downstream siltation. Other indirect services that this study considers are flood control and water regulation.

Option values refer to all use values (both direct and indirect) that can be realized at some point in the future. The definition adopted here is limited to uncertain benefits, i.e. already-ascertained benefits merely postponed for future use (such as in the case of commercial timber) are not considered.[3] Two of the best examples of this are future discoveries of medicinal and agricultural uses for plants, and future findings of new ecological benefits contributed by the forest. This study only considers the former in its estimates, given no reliable estimates of future ecological discoveries.

Finally, existence value is without a doubt the most elusive among the types of value noted. While most agree that it is 'non-use' in nature, there are many fundamentally distinct perspectives. For example, Madariaga and McConnell (1987) associate with existence value any non-use value, or even some types of use value like 'vicarious consumption' (e.g. viewing videos or TV programs about tropical wildlife or the forest in general). At the other extreme, Bergstrom and Reiling (1995) limit existence values merely to what the authors refer to as cognitive value, or the value in being able to 'think about' the resource. The range of existence value estimates considered in this study reflect this wide difference in perspectives.

Although TEV encompasses values that might overlap, the overestimate resulting from aggregation of all value types will in most cases probably not be too severe. This is assuming, of course, that only the sustainable portion of direct benefits is counted, since extracting forest resources at an unsustainable rate leads to the ultimate exhaustion — or at least profound alteration — of the forest.[4]

[2] Also important, though not considered in this study, is the 'human habitat' value experienced by indigenous peoples like the *Yanomami* and the *Kayapó*.

[3] Many (e.g. Pearce, 1991) do not make a distinction between the two, but some do, such as Groombridge (1992), and Kramer et al. (1992). Groombridge, however, counts both certain and uncertain future benefits in TEV, designating the former option value, and the latter 'quasi' option value.

[4] The 'sustainable portion' is the extraction level that would allow for preservation of the forest stock. This amount is equal to the level of growth, or natural regeneration, of the forest.

A more serious objection might be that foregone benefits from forest conservation (e.g. ranching or farming revenues) ought to factor into TEV-adjusted income. While it is true that this 'opportunity cost' does not figure in TEV-adjusted income if the forest is conserved, neither do the forest conservation benefits. Only when the Amazon is deforested do the lost conservation benefits appear as 'negative income', and in such a case there is no associated opportunity cost, since there are presumed economic revenues associated with deforestation. Thus, TEV-adjusted income is consistent in its treatment of costs and benefits. In contrast, conventionally-measured income is clearly inconsistent under the deforestation option, since ranching or farming revenues count while foregone conservation benefits do not.

This study estimates the TEV for a representative hectare of area of Amazonian forest, and assesses the economic loss, in relation to total income, attributable to deforestation in the period spanning 1978 and 1993. These losses are deducted from Brazilian gross income, and growth rates for the revised income measure are compared to those for per capita GDP.

3.2. Data

Most of the numbers employed in the calculations are drawn from other studies. In addition to listing the sources for these estimates, Table 1 presents a few details on the methodology for each. Two caveats are worth mentioning. First, many of the cited studies do not pertain to the Amazon nor, for that matter, to Brazil. They are, nevertheless, employed, absent an adequate selection of corresponding Brazilian case studies. Second, calculating a general per-hectare value for the Brazilian Amazon implies that the Amazon's vast expanse is of uniform 'quality'. Again, this simplifying assumption is made necessary by the limited available data.

The sustainable Amazonian timber harvest is based on an annual natural regeneration rate of 0.51 m^3/ha.[5] The timber net price ($708, 1993 prices) is a per-ton rather than per-cubic meter measure, so the product of the growth increment and the timber net price is multiplied by 0.85, the ratio of conversion between tons and cubic meters of timber, yielding the $307 ha/yr estimate. Both the regeneration figures and the conversion ratio are from Serôa da Motta and May (1992).

The replacement method is used to assess the value of nutrient losses resulting from soil erosion. Information on per-hectare tonnage losses, nutrient-fertilizer conversion ratios, and fertilizer prices are from Solórzano et al. (1991), Bastos Filho (1995), and Cavalcanti (1995). Data on the soil attributes for different Amazonian regions are from the Brazilian Institute of Geography and Statistics (IBGE, 1994). The estimated 'on-site' soil erosion cost in the Amazon is $68 ha/yr. In the absence of information on the 'off-site' (or downstream) costs, they are approximated here by extrapolating an on-site to off-site cost ratio from three other studies (Cruz et al., 1988; Dixon and Hodgson, 1988; Chopra, 1993), and applying it to Brazil.[6] The ratio, 2:5, yields an estimate of $170 ha/yr that the Amazon contributes in off-site erosion control services. Thus, the value of the combined on-site and off-site services is $238 ha/yr.

For the remaining benefit categories, the calculated annual per-hectare value is simply the mean of the estimates from the corresponding studies. Only one study was cited for the flood control estimate, as well as for the one for water regulation.

The annual TEV for a representative hectare of Amazon rain forest is summarized in Table 2. Total direct value is $549 (1993 prices), and indirect value equals $414 ha/yr.[7] Together, these two types of value account for over four-fifths of the Amazon's TEV. At $307, sustainable timber accounts for well over half of the direct value subtotal of $549. Foodstuffs contribute $131, and other

[5] The 0.51 figure is the weighted average (by area) of the growth rates in the nine individual Amazon states.

[6] Although crude, this method is certainly superior to assuming zero downstream effects.

[7] In truth, there is no consistent base year, given the extensive number of studies that were consulted. Nevertheless, since the resource values are often rough estimates anyway, it is acceptable to simplify by ascribing all the estimates to 1993, the final year surveyed.

Table 1
Survey of tropical forest values

Forest service	Value ($/ha per year)	Source	Comments
Sustainable timber	307	Author's calculations	Based on Serôa da Motta and May, 1992 (see text).
Food (fruits, nuts)	400	Peters et al. (1989)	Study on the Mishana region of the Peruvian Amazon. Authors compile data on the average number of trees per hectare of each relevant species, the annual fruit production for each type of tree, and the net price for each type of fruit.
	46	Grimes et al. (1994)	Study coverage was the Ecuadorian Amazon. Only accounted for a subset of available food, as non-food raw materials and medicinal benefits were also surveyed.
	59	Anderson et al. (1991)	Limited to value estimates for the babassu palm tree in the Brazilian Amazon.
	20	Pinedo-Vasques et al. (1992)	Authors surveyed the San Rafael reserve in Peru which, by their admission, is much less biologically diverse than others, such as the Mishana area surveyed by Peters et al. (1989).
Other raw materials	22	Peters et al. (1989)	Mishana, Peruvian Amazon. Only latex considered among non-food items.
	61	Grimes et al. (1994)	Ecuadorian Amazon. Calculated value based entirely on forest supply of Protium, a ceramic resin.
	116	Godoy et al. (1993)	Case study on the different uses of the Mexican te'lom forest groves. Authors base their estimate on an earlier study, but deduct projected timber and coffee revenues.
	98	Chopra (1993)	Based on the Indian forest's annual per-hectare output of fodder and products such as sal leaves, tassan cocoons, bidi leaves, lacquer, and dyes. Reported value is mean of minimum ($89) and maximum ($107) values estimated by Chopra.
Recreation	50	Tobias and Mendelsohn (1991)	Travel cost method employed in the Monteverde Cloud Forest Reserve (MCFR), Costa Rica. Calculated NPV (domestic and international) is $12.5 million. Factoring in MCFR's 10 000 ha, and the authors' 4% discount rate (to convert NPV to annual flow) the per-hectare figure is $50.
	5	Ruitenbeek (1992)	Study of the Korup National Park, Cameroon. Analytical criteria and shadow prices based on author's discussions with government planners, though no further details are provided.
	55	Edwards (1991)	Author employs hedonic analysis to estimate a demand function for vacations to the Galapagos islands, Ecuador. Calculated annual revenue is $39.7 million which, given the 720 000 ha in the 45 islands, translates to $55 per ha/yr.
Climate regulation	100	Brown and Pearce (1994)	Estimate based on projected average carbon sequestration rate per hectare of virgin tropical forest, and estimate of what percentage (2/3, per the authors) is released into the atmosphere when the area is deforested. Damage per ton estimate, $10, is extrapolated from other studies. Based on study of a variety of the world's tropical forests.
	70	Fearnside (1997)	Study on the Brazilian Amazon. Author provides a range of damage estimates (from $1.80 to $66 per ton), based on other global warming studies. I employ his 'medium' estimate of $7.30 per ton in arriving at the estimate here.
	336	Krutilla (1991)	Survey of Malaysian tropical forest. Author bases estimates on costs associated with either cutting back in fossil-fuel emissions or protection of coastlines, increased air conditioning, etc. Discount rate of 8% is assumed to convert NPVs to annual flows.

Table 1 (Continued)

Forest service	Value ($/ha per year)	Source	Comments
	59	Pearce (1991)	Estimates per-hectare deforestation-induced carbon release in Brazil to be 90.8 tons. Discount rate of 5% assumed.
	200	Pearce and Moran (1994)	Range of estimates provided, from low of $80 per ha/yr to high of $320. The mean ($200) is used in this study.
Flood control	4	Ruitenbeek (1992)	Study of Korup National Park, Cameroon. Value of lost flood control benefits assumed to be a function of size of population affected, deforestation in relation to remaining area, per capita income of affected population, and flood frequency.
Water regulation	19	Fearnside (1997)	Study on the Brazilian Amazon. Author attributes economic loss to the loss of the water regulation function of the trees. Again, three estimates are given (low, medium, and high), the medium estimate being used in this study.
Erosion control	238	Author's calculations	Nutrient loss estimates based on the work of Bastos Filho (1995), Cavalcanti (1995), and Solórzano et al. (1991), and data from the IBGE (1994). Off-site (or downstream) effects based on the work of Chopra (1993), Dixon and Hodgson (1988), and Cruz et al. (1988). Value of downstream costs for Brazil extrapolated from these studies.
Option benefits	32	Adger et al. (1995)	Mexico case study. Authors calculate the expected future benefit from estimates of the number of plant species in the forest, the probability of a given species being useful, the royalty rate for the host country, the 'likely' value if product is internationally traded, and the area of the forest.
	11	Pearce and Moran (1994)	Worldwide survey of tropical forests. Same formula used as by Adger et al. (1995).
	17	Mendelsohn (1997)	Same approach as in Adger et al. (1995), and Pearce and Moran (1994). Study of several tropical forest areas.
	20	Fearnside (1997)	Value of biodiversity maintenance in the Brazilian Amazon assumed to be $10 per ha/yr (low estimate), $20 (medium), or $30 (high). Approximations based on a possible range of annual payments international agencies could pay lesser-developed countries to preserve their tropical forests (from the work of Cartwright, 1985).
	9	Grimes et al. (1994)	Estimate of the annual per-hectare flow associated with three medicinal tree barks found in the Ecuadorian Amazon.
Existence benefits	3	Kramer and Mercer (1997)	Authors distribute questionnaires to US citizens, asking them how much they would be willing to pay to preserve an additional five percent of all the world's tropical forests. Two methods, payment card and referendum, used.
	238	Echeverría et al. (1995)	Contingent valuation study on the Monteverde Cloud Forest Reserve (MCFR), Costa Rica. Both Costa Rican and non-Costa Rican visitors are surveyed.
	8	Ruitenbeek (1992)	Considers estimates for six areas: the Beni Reserve in Bolivia, Amazonian Parks in Ecuador, St. Paul Park in the Philippines, Santa Rosa Park and Monteverde Cloud Forest, both in Costa Rica, and Oban Park in Nigeria.
	5	Adger et al. (1995)	Existence value inferred from the revealed value for a sample of transactions related to forest conservation in Mexico, such as contributions to conservation organizations, a tourism survey, and debt for nature swaps.
	18	Pearce (1991)	Author extrapolates Amazon value from US studies, providing a ha/yr existence value range from $10–26.
	893	Chopra (1993)	Author argues that most existence value estimates are significant underestimates because they are derived from a relatively small sample rather than the world population. He assumes tropical forest existence value to equal 91% of total use value. The calculated total use value for the Amazon is $981 ha/yr; 91% of this figure is $893.

raw materials, $74. Recreation generates $37 ha/yr. The protection the Amazon provides against soil erosion is, at $238, the most valuable of the calculated indirect benefits. Also significant is climate regulation, at $153. Water regulation contributes $19, and flood control a mere $4. Finally, existence benefits contribute $194 ha/yr, and option value only $18. The standard deviation for existence benefits is enormous ($354), however, suggesting that the $194 value estimate is of questionable reliability. The TEV per ha/yr is $1175.

3.3. Scarcity adjustment

The $1,175 ha/yr figure is the estimated TEV for the year 1993. It is reasonable to expect the real value per ha/yr to have been lower in 1978, when there existed more forest area — that is, when tropical forest 'scarcity' was lower. Adjustments for the latter as well as intervening years are therefore required.

If, as seems probable, the Amazonian ecosystem is subject to non-linearities — i.e. sudden dramatic increases in the magnitude of damage once forest area is reduced below some critical threshold — deforestation potentially results in rapid increases in marginal unit conservation value (see Fig. 1a).[8] But given both inadequate means of estimating the relevant threshold values — the magnitude ($) of the 'jump' as well as at what point it occurs — and the fact that such a critical point, if it exists, does not yet appear to have been reached, we need more conservative assumptions. Lacking a more reliable method of assessment, I assume a rectangular hyperbolic demand function for the forest resource (Fig. 1b). In addition to ensuring that the forest unit values are not overestimated (no threshold effects), the advantage to such an approach is in its simplicity. Annual unit TEV varies depending on remaining forest stock, with product of unit TEV and total area remaining constant. Adjusted in this

Table 2
Estimated Amazonian rain forest value

Type of value	Value per ha/year
Direct use	
Timber	$307
Food	131
Non-food raw materials	74
Recreation	37
Total	549
Indirect use	
Climate regulation	$153
Disturbance regulation	4
Water regulation	19
Erosion control	238
Total	414
Option	
Unknown future medicinal benefits	18
Total use benefits	$981
Existence benefits	194
Grand total	$1175

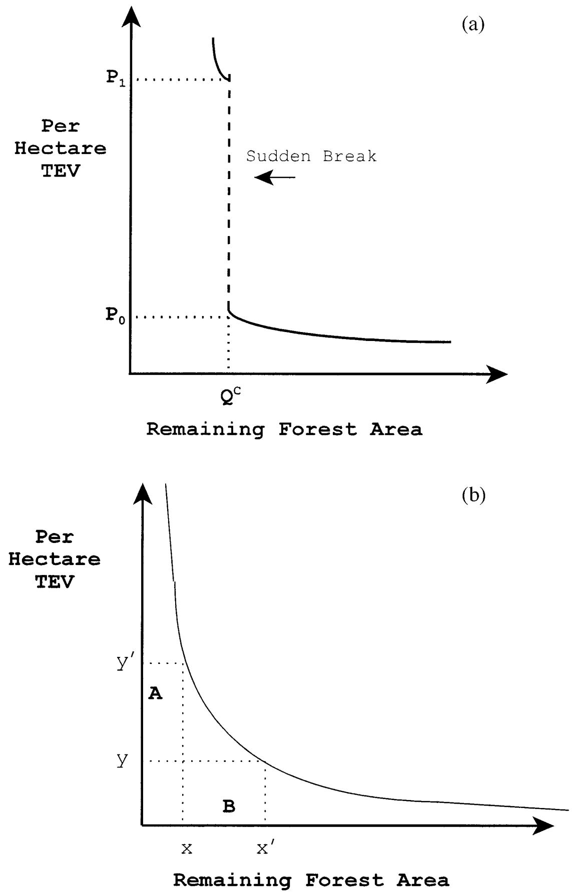

Fig. 1. Relationship between remaining area and Amazon unit value. (a) Discontinuous relationship (b) Rectangular hyperbolic relationship.

[8] See Costanza et al. (1997) and Fearnside (1997).

way, real TEV ha/yr (in 1993 $) does not vary substantially, rising from $1088 ha/yr in 1978 to $1175 in 1993.[9]

3.4. Discounting

Finally, proper assessment of deforestation loss requires calculation of net present values (NPVs). A lost hectare of forest signifies not only dissipation of the annual per-hectare flow of benefits, but of all future flows, discounted in perpetuity. One might, at first glance, contend that discount rates do not apply to conservation benefits. After all, if a hectare of standing forest is protected, the value of its benefits cannot, generally speaking, be ‘cashed in’ and invested in physical capital. The fallacy in such thinking is that the discount rate can be seen as representative not only of the opportunity cost of capital, but also of the social rate of time preference. Since future benefit flows provide value to society, they should be aggregated in the valuation of the Amazon’s conservation benefits. Discounting is necessary insofar as the social value of future benefits is less than that of present benefits.

Since the Amazonian ecosystem is both unique and irreplaceable, there are grounds for favoring a relatively low discount rate. While suitable for evaluating resource extraction projects, a discount rate on the order of 10% is arguably too high for our purposes. A rate in the 1–2% range, on the other hand, while perhaps appropriate for some critical or rare resources, arguably represents undue prudence in the present context. An intermediate discount rate of 5% is generally considered to be a reasonable approximation of the social rate of time preference, particularly with issues relating to natural resource depletion (see, e.g. Pearce et al., 1990). It is therefore the rate of choice in the present study.

4. Total economic loss from Amazonian deforestation

The deforestation estimates in this study are based on data from Brazil’s National Institute for Spatial Research (INPE, 1995, 1997), Serôa da Motta and May (1992), and Moran et al. (1994). As seen in Table 3, annual Amazonian deforestation accelerated from the late 1970s to the mid 1980s, more than doubling from 1978 to 1986. Starting in 1987, however, the annual amount deforested began to recede, and by 1991 almost returned to the 1978 level. The annual area deforested picked up anew after 1991, although in 1993 it was still significantly less than it had been in the mid-1980s. By 1993, the total Amazonian expanse had been reduced by 7.5% from the 1978 level.

The percentage reduction varies considerably by state (Table 4).[10] Not surprisingly, the most remote

Table 3
Annual Amazonian deforestation (areas in ‘000 ha)

Year	Area deforested	Area remaining
1978	1302	393 542
1979	1560	392 414
1980	1706	391 044
1981	1865	389 513
1982	2040	387 798
1983	2230	385 869
1984	2439	383 690
1985	2667	381 222
1986	2916	378 413
1987	2649	375 203
1988	2198	372 304
1989	1564	369 948
1990	1393	368 383
1991	1360	366 991
1992	1418	365 631
1993	1555	364 212

Table 4
Area deforested, 1978–1993, % change from base year

State	Area deforested (%)
Acre	6.2
Amapá	1.2
Amazonas	1.5
Maranhão	34.3
Mato Grosso	16.2
Pará	9.1
Rondônia	18.4
Roraima	2.8
Tocatins	38.2

[9] Although, as is shown, the 1993 figure varies according to Amazonian state. Details on calculations for the intervening years are found in Appendices A–C.

[10] See Appendices A and B for the data on which these calculations are based.

states (Acre, Amapá, Amazonas, Pará, and Roraima) have suffered the least deforestation in relation to remaining forest area. States to the east (Maranhão) and south (Rondônia, Mato Grosso, and Tocatins) have been more adversely affected, no doubt due to their easier accessibility from the more densely populated and developed states along the Atlantic coast.

The scarcity adjustment discussed in the previous section is applied to the individual states, rather than to Brazilian Amazonia in its entirety. Doing so permits us to reflect the widely disparate deforestation rates. As we would expect, there is moderate variation in the unit values of forest for each state. For example, the 1993 value of a ha/yr of forest in Maranhão, where deforestation has been massive in relation to remaining area, is significantly greater than for, say, Amapá, which still retains the great majority of its original forest cover.[11]

Fig. 2 presents the ratio, for each state, of NPV loss from deforestation to income. The latter figures are obtained from the IBGE (1978, 1986, 1994). Notice that, although many exhibit trends consistent with the trend for deforestation in Amazonia as a whole — that is, rising until a peak in the mid-1980s, and declining abruptly thereafter — the economic losses relative to income vary considerably. In states such as Mato Grosso and Tocatins, lost NPV from deforestation dwarfs income in each of the years studied. In states like Amapá and Amazonas, in contrast, income exceeds lost NPV, at least in most years.

Not surprisingly, NPV loss for Amazonia exceeds joint income for the nine states in every year of the study (Table 5). This result reflects the relatively meager share of Brazilian GDP garnered by the Amazonian states — even at its highest, in 1993, only 7.4% — as well as the magnitude of deforestation. The NPV loss in relation to Brazilian GDP is reported in the second column; the losses range from 7.9 to 18.5% on conventionally measured national income.

[11] See Appendix C for the time series for all nine states.

Finally, while per capita GDP grew at a rate of 0.7% per annum from 1978 to 1993, the rate of growth of national income per capita falls to 0.3% if, as in the WRI studies, we incorporate reductions to the Amazonian forest 'stock'. Indeed, for the sub-period spanning 1978 and 1986, the rate is negative (−0.1%), suggesting that 'true' per capita income declined. These results pertain to Brazil as a whole; the story for the individual Amazonian states is doubtless far more dismal. The findings of this study, therefore, call into question the sustainability of Brazil's GDP growth, as it is conventionally measured.

5. Conclusion and parting thoughts

While deforestation has, to this point, been largely confined to the more accessible regions of Brazil, in aggregate terms the economic loss it has caused has been enormous. Calculated NPV of the annual loss consistently exceeded income in many Amazonian states, and total loss was substantial even when compared to overall Brazilian GDP. Although the country's annual per capita GDP growth from 1978 to 1993, at 0.7%, is not awe-inspiring, its performance is even worse (0.3%) if we adjust the income accounts to reflect the K_N stock reduction. If we isolate the sub-period from 1978 to 1986 (the peak year in physical magnitude of deforestation), the per capita 'revised' income growth rate is −0.1%.

As expected, taking total economic value into consideration results in estimated natural capital losses considerably greater than those reported in most previous case studies. One such study (Repetto et al., 1989) did report a very high ratio of K_N loss to GDP for Indonesia (exceeding 20% for some of the years it surveyed), but this ratio factored in the entire country's losses. The present study, in contrast, only accounts for losses in the nine Amazonian states. These findings support the claim that growth which entails continued depletion of a country's natural resource base may be unsustainable. In other words, unless modes of economic activity that are less intensive on

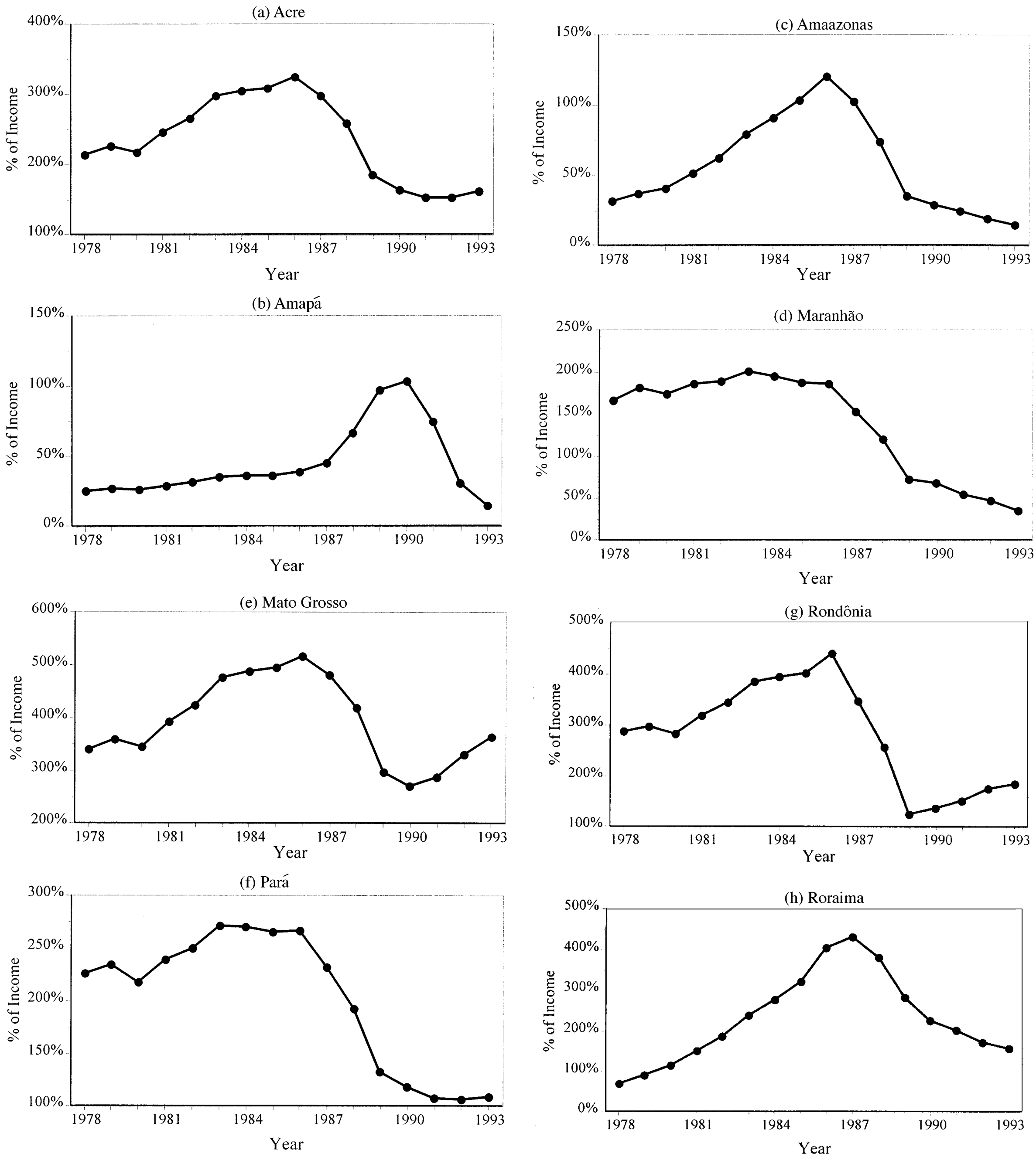

Fig. 2. Annual net present value of loss as a percent of income, by state.

Brazil's natural resources become more widespread, continued K_N depletion may, because the Amazon's expanse is finite, eventually act as a brake on conventionally measured income growth. A more sustainable strategy for Brazil requires greater attention to the long-term conservation benefits provided by Amazonia, and the continued development of new industries to dis-

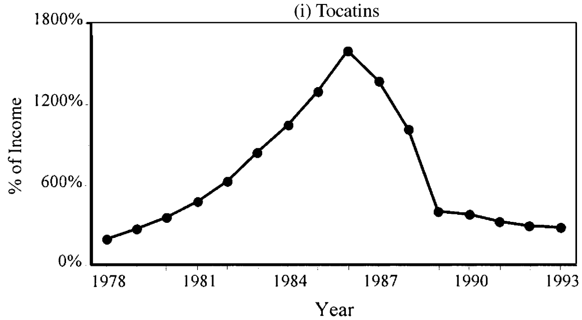

Fig. 2. (*Continued*)

Table 5
Annual net present value of loss as a % of income

Year	Loss as % of regional income	Loss as % of Brazilian GDP
1978	180.7	7.9
1979	195.0	9.1
1980	189.0	9.4
1981	214.0	11.1
1982	230.9	12.5
1983	259.8	14.7
1984	268.0	15.8
1985	274.9	17.0
1986	292.2	18.5
1987	254.3	16.4
1988	205.1	13.6
1989	128.3	8.7
1990	118.0	8.2
1991	113.2	8.0
1992	117.3	8.5
1993	121.0	9.0

place — or reduce the impact of — ranching and farming.

There are at least three possible routes to improving on the accuracy and comprehensiveness of the results presented here. First, economic activity in the non-Amazonian states could also be considered. While virgin rain forest is likely to possess a greater unit TEV than other types of terrain outside Amazonia, a more complete accounting would also include these values. Granted, this would make the analysis considerably more complex. Not only do other types of terrain require new estimates, we can expect non-Amazonian states, in general, to have far more diverse environments than Amapá or Roraima, which are still mostly virgin forest.

Second, the method employed in this study to account for scarcity remains crude. A more accurate accounting would reflect potential discontinuities in the demand function for forest amenities. Finally, it was impossible to account for the likely consequences of deforestation stemming from interdependence among distinct indirect environmental services and functions (indeed, even ecologists have yet to understand these fully). Exclusion of these potential problems most likely results in an understatement of TEV.

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Appendix A. Annual Amazonian deforestation, by state (area in '000 ha)

Year	Acre	Amapá	Amazonas	Maranhão	Mato Grosso	Pará	Rondônia	Roraima	Tocatins
1978	31.0	2.7	45.6	200.4	248.6	447.1	86.2	3.9	63.4
1979	38.0	3.4	60.7	231.6	305.1	533.4	110.9	5.6	81.3
1980	43.0	3.9	77.4	239.7	346.0	579.7	134.7	7.7	98.2
1981	48.8	4.5	98.7	248.1	392.3	630.0	163.7	10.7	118.6
1982	55.3	5.1	125.8	256.8	444.8	684.7	198.8	14.9	143.3
1983	62.7	5.9	160.3	265.8	504.3	744.2	241.5	20.6	173.0
1984	71.0	6.8	204.4	275.1	571.8	808.8	293.3	28.6	209.0
1985	80.5	7.8	260.5	284.7	648.4	879.0	356.3	39.7	252.5
1986	91.2	8.9	332.1	294.7	735.1	955.3	432.8	55.0	304.9
1987	86.8	10.7	298.3	245.3	717.2	865.7	366.6	62.5	246.0
1988	75.3	15.7	219.2	187.0	630.3	725.9	278.8	56.4	167.1
1989	56.4	23.7	112.7	114.8	472.7	526.1	149.1	44.6	64.2
1990	48.1	24.2	89.9	104.1	417.8	456.7	161.6	35.0	55.4
1991	45.0	17.4	76.5	81.6	453.6	419.5	188.3	31.9	46.0
1992	45.3	7.2	60.6	69.6	527.4	414.7	226.3	27.8	39.6
1993	50.0	3.6	51.3	55.9	617.0	450.5	260.5	27.5	38.7

Appendix B. Remaining forest area, by state (area in '000 ha)

Year	Acre	Amapá	Amazonas	Maranhão	Mato Grosso	Pará	Rondônia	Roraima	Tocatins
1978	15 015	12 423	153 932	9209	49 550	111 176	19 862	16 872	5505
1979	14 984	12 420	153 886	9009	49 301	110 729	19 775	16 868	5441
1980	14 946	12 417	153 825	8777	48 996	110 195	19 664	16 863	5360
1981	14 ,903	12 413	153 748	8537	48 650	109 616	19 530	16 855	5262
1982	14 854	12 409	153 649	8289	48 258	108 986	19 366	16 844	5143
1983	14 799	12 404	153 523	8032	47 813	108 301	19 167	16 829	5000
1984	14 736	12 398	153 363	7767	47 308	107 557	18 926	16 809	4827
1985	14 665	12 391	153 159	7492	46 737	106 748	18 633	16 780	4618
1986	14 585	12 383	152 898	7207	46 088	105 869	18 276	16 741	4366
1987	14 494	12 374	152 566	6912	45 353	104 914	17 844	16 686	4061
1988	14 407	12 363	152 268	6667	44 636	104 048	17 477	16 623	3815
1989	14 331	12 348	152 049	6480	44 006	103 322	17 198	16 567	3648
1990	14 275	12 324	151 936	6365	43 533	102 796	17 049	16 522	3583
1991	14 227	12 300	151 846	6261	43 115	102 339	16 887	16 487	3528
1992	14 182	12 282	151 770	6179	42 662	101 920	16 699	16 455	3482
1993	14 137	12 275	151 709	6110	42 134	101 505	16 473	16 427	3442

Appendix C. Per-hectare value for each Amazonian state (1993 US$)[a]

Year	Acre	Amapá	Amazonas	Maranhão	Mato Grosso	Pará	Rondônia	Roraima	Tocatins
1978	1088	1088	1088	1088	1088	1088	1088	1088	1088
1979	1090	1088	1088	1112	1093	1092	1093	1088	1101
1980	1093	1089	1089	1142	1100	1098	1099	1089	1117
1981	1096	1089	1089	1174	1108	1103	1106	1089	1138
1982	1100	1089	1090	1209	1117	1110	1116	1090	1164
1983	1104	1090	1091	1247	1128	1117	1127	1091	1198
1984	1109	1090	1092	1290	1140	1125	1142	1092	1241
1985	1114	1091	1093	1337	1153	1133	1160	1094	1297
1986	1120	1092	1095	1390	1170	1143	1182	1097	1372
1987	1127	1092	1098	1450	1189	1153	1211	1100	1475
1988	1134	1093	1100	1503	1208	1163	1236	1104	1570
1989	1140	1095	1101	1546	1225	1171	1257	1108	1642
1990	1144	1097	1102	1574	1238	1177	1267	1111	1671
1991	1148	1099	1103	1600	1250	1182	1280	1113	1698
1992	1152	1100	1103	1621	1264	1187	1294	1116	1720
1993	1156	1101	1104	1640	1279	1192	1312	1117	1740

[a] Calculation: to simplify, I assume the $1175 per ha/yr figure is for 1993. The corresponding figure for 1978 is $1088. I obtain this number by multiplying the area remaining in Amazonia in its entirety in 1993 (36.4 million ha) by $1175, and dividing by the remaining area in 1978 (39.4 million ha). The rationale for this is my assumption of a rectangular hyperbola demand curve for the forest resource. Therefore, unit value times quantity available must always be equal. Thus, with 1978 as the starting point, the above numbers for the states are obtained by multiplying $1088 by the remaining area in 1978 for a given state, and dividing the product by the area remaining in each subsequent year.

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