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AN ECONOMIC APPROACH TO SAVING THE TROPICAL FORESTS

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1. The Issue

The fate of the tropical forests is currently an issue of major international concern. Television and film images of burning forests as they are cleared for agriculture, road building, timber extraction and industrial development abound. Most of the appeals to 'save the rain forest' are emotionally directed and aim to raise funds to secure outright protection, especially where indigenous peoples are present, or to assist with sustainable uses of the forests. While such campaigns are wholly understandable and generally justifiable, there are other pressure points in the world economic system which promise greater efficacy of action. By and large, these involve demonstrating to governments and international agencies, in the rich and poor world alike, that tropical forests have economic values when they are conserved and utilised sustainably. Moreover, these economic values could be significantly greater than the alleged 'development' values derived by destroying these unique assets. The purpose of this paper is to outline an approach to the economic valuation of tropical forests and to illustrate it with examples of the kinds of anti-conservation bias that exists in prevailing systems of economic incentives.

There are various land use options for tropical forests. They can be 'left alone'. If no human use of the forest land is permitted at all, we might refer to this land use option as <u>preservation</u>. Maintaining the forest stock in broadly its original state but allowing human use of it can be defined as <u>conservation</u>. There will be a broad spectrum of conservation options. Limited selective logging might be permitted with subsequent natural or managed regeneration of the removed timber. Forest products, such as latex production or rattan gathering, might be 'harvested' without removing timber stock. Agricultural clearance on a 'shifting cultivation' might be practised with full regeneration of the forest being allowed as a new plot is exploited. Some experts would not regard shifting cultivation as a conservation option: the terminology is not universally agreed. But the basic idea remains that conservation involves use without there being significant destruction of the forest ecosystem. Above all, any use option that produces <u>irreversible</u> effects is not a conservation use of the land. 'Development' options would then include clearance for agricultural use without any intent of securing regeneration, clear-felling of timber without regeneration, removal of the forest for use of the land for infrastructure, e.g. a road or mining or industrial development. By and large, development options preclude the regeneration of the forest because of damage to forest soils arising from the development programme's use of the land. This not inevitable, but it is very likely.

2. The Rate of Deforestation

Global concern about the rate of tropical deforestation accelerated in the 1980s. Data for all types of forest are approximate. Different sources use different definitions of 'tropical forest' and different definitions of 'deforestation', but annual rates of deforestation at the end of the 1980s appear to be somewhere between 14 and 17 million hectares per annum Table 1]. Depending on how forest area is defined, this rate of deforestation may be some 1.8 -2.2% of the remaining area of tropical forest (taken to be some 8 million km^2, or 800 million hectares). Although comparisons are difficult because of changing definitions, deforestation rates may have been running at far less, around 0.6% p.a., in the late 1970s.

The focus of attention on tropical forests has arisen because of the sheer diversity of functions which they serve, the uniqueness of primary forest in evolutionary and ecological terms, and the accelerating threat to their existence. In the briefest of terms, tropical forests:

are the homeland of many indigenous peoples, some practising shifting cultivation

provide the habitat for extensive fauna and flora (biodiversity), which are
- valued in itself
- valued for educational purposes
- valued for crop-breeding purposes
- valued for medicinal purposes,

supply hardwood timber,

supply other forest products such as fruit, nuts, latex, rattans, meat, honey, resins, oils etc.,

provide a recreational facility (e.g. 'ecotourism')

protect watersheds in terms of water retention, flow regulation water pollution and organic nutrient cleansing,

act as a store of carbon dioxide so that, while no net gains in the flow of carbon dioxide accrue to climax forests, carbon dioxide is released, and a cost ensues, if deforestation occurs,

fix carbon in secondary forests and in reforested areas,

serve a possible regional microclimatic function

TABLE 1 RATES OF TROPICAL DEFORESTATION, 1980s

	Rates of Deforestation (million hectares p.a.) Closed Forest Only		
	Late 1970s(1)	Mid 1980s(2)	Late 1980s(3)
S.America	2.67	9.65(4)	6.65
C.America	1.01	1.07	1.03
Africa	1.02	1.06	1.58
Asia	1.82	3.10	4.25
Oceania	0.02	0.02	0.35
Totals	6.54	14.90	13.86
Adjusted Total(5)	n.a	15.29	14.22
% of remaining forest	0.6	n.a	1.8-2.1

Notes and Sources: (1) Late 1970s data for the 34 countries covered in Myers (see below) from Food and Agriculture Organisation, Tropical Forest Resources, Rome 1981.

(2) Various years to 1986, taken from World Resources Institute, World Resources 1990-1991, Oxford University press, Oxford, 1990, Table 19.1. In turn, the estimates are based on FAO sources, including an update for some countries of the 1981 estimates, and some individual sources. Note that the estimates cover closed forests only. Closed forests refer to dense forests in which grass cover is small or non-existent due to low light penetration through the forest canopy.

(3) N.Myers, Deforestation Rates in Tropical Forests and Their Climatic Implications, Friends of the Earth, London, December 1989. Myers' estimates cover 34 countries accounting for 97.3% of the extent of tropical forest in 1989.

(4) This figure appears out of line with other estimates and is accounted for mainly by a single country-Brazil. Whereas Myers estimates 5 million ha. p.a. loss for Brazil in 1989, the World Resources Institute figure for mid 1980s is some 8 million ha.p.a. for closed forest loss.

(5) Myers estimates that 40 other countries with small tropical forests suffered deforestation rates totalling 0.36 million ha.p.a in 1989. We have 'grossed up' the World resources Institute figures by the same factor (14.22/13.86) to ensure comparability.

All these functions are economic functions because they contribute to human welfare either directly or indirectly[1]. The issue to be addressed is how to determine the 'total economic value' of a tropical forest. The issue is important because decisions about the use of tropical forest land are currently made in the context of an imperfect understanding of the total functions of the forest. Even if the functions are broadly understood, only some of them enter into the economic calculus that determines land use. In particular, the direct use values (timber, agricultural land) dominate land use decisions and the wider environmental values are neglected. The resulting asymmetry of values explains much deforestation and its analysis indicates some policy instruments for better forest management.

3. Total Economic Value

One approach to decision-making about tropical forest use is the cost-benefit approach (CBA). Under CBA, decisions to 'develop' a tropical forest would have to demonstrate that the net benefits from development exceed the net benefits from 'conservation'. Development here is taken to mean some use of the forest that would be inconsistent with retention of the forest in at least approximately its natural state. Conservation could have two dimensions: preservation, which would be formally equivalent to outright non-use of the resource, and conservation which would involve limited uses of the forest consistent with retention of natural forest. The definitions are necessarily fuzzy. Some people would argue, for example, that ecotourism is not consistent with sustainable conservation, others that it may be. Accepting the lack of precise lines of differentiation, the CBA rule would be to develop if and only if:

$$DEVBEN - DEVCOST > CONSBEN - CONSCOST \quad (1)$$

That is, the development benefits minus the development costs must be greater than the benefits of conservation minus the costs of conservation. Rearranging (1), we have:

$$DEVBEN - DEVCOST - NetCONSBEN > 0 \qquad (2)$$

It is not sufficient, therefore, for the net benefits of development to be positive. The forgone net benefits of conservation must also be subtracted from net development benefits[2].

Typically, development benefits and costs can be fairly readily calculated because there are attendant cash flows. Timber production, for example, tends to be for commercial markets and market prices are observable. Conservation benefits, on the other hand, are a mix of associated cash flows and 'non-market' benefits. This fact imparts two biases. The first is that the components of inequality (2) with associated cash flows are made to appear more 'real' than those without such cash flows. There is 'misplaced concreteness' and decisions are likely to be biased in favour of the development option because conservation benefits are not readily calculable. The second bias follows from the first. Unless incentives are devised whereby the non-market benefits are 'internalised' into the land use choice mechanism, conservation benefits will automatically be downgraded. Very simply, those who stand to gain from, say, timber extraction or agricultural clearance cannot consume the non-marketed benefits. This 'asymmetry of values' imparts a considerable bias in favour of the development option.

CONSBEN in inequalities (1) and (2) is measured by the <u>total economic value</u> of the tropical forest. Total economic value (TEV) for a tropical forest is explained in Table 2. TEV comprises <u>use</u> and <u>non-use values</u>. Conservation is consistent with some sustainable uses of the forest, including sustainable timber harvesting.

TABLE 2 TOTAL ECONOMIC VALUE IN THE TROPICAL FOREST CONTEXT

Total Economic Value =

Use Value +				Non-Use Value
(1)	(2)	(3)	(4)	(5)
Direct + Value	Indirect Value	+ Option Value	[Quasi-Option Value]	+ Existence Value
Sustainable Timber				
Non-Timber Products	Nutrient Cycling	Future Uses as per (1) +(2)		Forests as object of intrinsic value, as a bequest, as a gift to others, as a responsibility (stewardship) Includes cultural and heritage values.
Recreation	Watershed Protection			
Medicine	Air Pollution Reduction			
Plant Genetics	Micro-climate			
Education				
Human Habitat				

<u>Direct</u> use values are fairly straightforward in concept but are not necessarily easy to measure in economic terms. Thus minor forest products output should be measurable from market and survey data, but the value of medicinal plants is extremely difficult to measure. <u>Indirect</u> values correspond to the ecologist's concept of 'ecological functions' and are discussed further below.

Option values relate to the amount that individuals would be willing to pay to conserve a tropical forest for future use. That is, no use is made of it now but use may be made of it in the future. Option value is thus like an insurance premium to ensure the supply of something the availability of which would otherwise be uncertain. While there can be no presumption that option value is positive it is likely to be so in the current context[3].

Quasi-option value has also been identified in the literature[4]. QOV is the value of information that arises between the choice of conservation or development now and development in the future. For example, the choice now for the tropical forest may be to conserve it or 'develop' it. If conservation is chosen, the choice in the next period can be either conservation or development. But if development is chosen and irreversible change occurs, then only development can be chosen in the next period. In between the two periods information may arise which enhances the value of preservation, e.g. a scientific discovery about some of the flora and fauna. Quasi option value is the value of learning about the future benefits that would be precluded by development now. It will be positive if the information depends on the passage of time, as one would expect it to be for tropical forest functions. Quasi-option value cannot be added to option value as they measure different concepts.

Existence value relates to valuations of the environmental asset unrelated either to current or optional use. Its intuitive basis is easy to understand because a great many people reveal their willingness to pay for the existence of environmental assets through wildlife and other environmental charities. Empirical measures of existence value, obtained through questionnaire approaches (the contingent valuation method), suggest that existence value can be a substantial component of total economic value. This finding is even more pronounced where the asset is unique[5], suggesting high potential existence values for tropical forests and especially for luxuriant moist forests.

From Table 2, then, total economic value can be expressed as:

TEV = Direct Use Value + Indirect Use Value + Option Value + Existence Value

It is important to note that the components of TEV cannot simply be aggregated. There are trade-offs between different types of use value and between direct and indirect use values. In practice, then, the TEV approach has to be used with care.
We address each component of TEV in turn.

4. Direct Use Values in the Tropical Forest

Direct use values may be classified broadly in terms of timber and non-timber uses. Non-timber products include fruits, nuts, rattan, latex, resins, honey, and wildmeat.

(i) Timber.

Logging for timber can be consistent with conservation if the timber management regime practises sustainable forestry. Sustainable forestry consistent with leaving the original ecosystem broadly intact effectively requires natural forest management, i.e. selective cutting combined with natural regeneration. Traditionally, natural management regimes have been regarded as loss-making unless:

- biological growth rates are very high
- stumpage prices (i.e. log prices) are high
- management is effective and at minimum cost
- the discount rate is low compared to typical commercial and even official government levels[6].

This bias explains the general absence of sustainable natural management systems in tropical forestry[7]. Inefficiency arising from governmental interference is of considerable importance as far as high cost non-sustainable management is concerned.

Table 4 shows some estimates of the financial profitability of different forestry systems in Indonesia. Six regimes are compared. TPI is a selective cutting system in which only the largest commercial trees (over 50 cm diameter at breast height) are taken. The management of TPI systems is crucial since careless selective cutting can damage the residual stock, reducing future harvests. In its ideal form, however, it is a sustainable system. CHR is 'complete harvesting and regeneration', i.e. harvesting all merchantable trees, followed by natural or enriched regeneration. INTD is an intensive dipterocarp system based on the idea of heavily managed plantations on clear-felled land. PULP refers to plantations of fast-growing species for pulp. SAWT refers to sawtimber plantations at 10 and 20 years rotations respectively. Environmentally, it seems reasonable to rank TPI above CHR[8]. INTD is an untried system which may or may not be environmentally better than CHR. SAWT and PULP are both *prima facie* environmentally undesirable since they are typically based on uniform plantings of non-indigenous species on cleared land. However, such plantations on currently unforested land could be important for 'carbon-fixing' purposes (see below).

Table 4

Comparative Financial Profitability
of Forest Management Systems in Indonesia

(Net Present Value: 1986 US$/Hectare)

Regime:	Discount Rate: 5%	6%	10%
TPI	2705	2409	2177
CHR	2690	2593	2553
INTD		2746	2203
PULP		2926	2562
SAW20		2419	2278
SAW10		2165	2130

Source[9].

Table 4 suggests that, on financial grounds, rapid growth plantations for pulp production are most desirable at an interest rate of 6%, and are equally ranked first at a 10% interest rate. Of the systems involving the least 'management', the selective cutting system is not favoured except at the low discount rate of 5%. Typically, rates of discount used for project appraisal in developing countries are 10% and above. Table 4 therefore bears out the general presumption that natural management systems based on selective cutting are unprofitable compared to managed intensive systems and, perhaps, clearer-cutting systems with some natural regeneration. There are many caveats to this conclusion, however. First, the results are likely to be location - specific. Second, they relate to financial profitability and not to economic worth. An economic assessment would allow for 'shadow' pricing, i.e. a valuation procedure that reflects the worth of the investment to the economy as a whole rather than to a forest concessionaire[10]. Third, the discount rate is seen to be crucial. Shadow pricing may dictate a lower rate depending on the nature of the rationale for discounting[11]. Nonetheless, a direct appeal to timber benefits is clearly a risky argument for defending the sustainable use of tropical forests.

(ii) Non-Timber Products

Non-timber products can be important sources of revenue. In Indonesia, for example, exports of non-timber forest products rose from $17 million in 1973 to $154 million in 1985, comprising 12 per cent of forest export earnings[12]. They rose to $238 million in 1987[13]. Exports of rattan alone were $80 million in 1985. Tropical forests also supply essential oils such as camphor, cinnamon, clove and nutmeg, a trade worth some $1 billion p.a.[14], although most of the output of these products comes from plantations. It cannot be assumed that non-timber product exploitation is itself free from environmental damage. The management record for many non-timber products is hardly better than that for tropical timber[15]. Analysis of fruit and latex yields in a one hectare plot of Peruvian Amazonian rainforest suggests that non-timber product revenues may actually exceed timber revenues[16]. The results are shown in Table 5.

Table 5

Timber and Non-Timber Revenues in a Peruvian Rainforest (Equitos)

(Net Present Value at 5%: US$ per hectare)

	Fruit and Latex	6330
plus	Selective Logging	490
	Total	6820
	Clear-Felling Timber	1000

Source: see endnote ?

The implication of Table 5 is that tropical forest conservation might be achieved by simple appeal to financial profitability. It is likely that much forest is unnecessarily damaged because of a failure to investigate alternative management regimes for alternative 'crops'. But there are several dangers in extrapolating from a one-hectare plot to entire forests. First, markets for non-timber products are very unlikely to be that big.

As production of non-timber products expands so their prices are likely to fall. Second, the Peruvian case considers a plot of land near to markets, whereas the major part of the tropical forest area will be distant from the market place, affecting transport costs. The analysis also raises an important question: if it is privately profitable to exploit forests for non-timber products, why isn't greater use made of them for this purpose ? Put another way, why doesn't the exercise of market forces produce this result ?

The answer to this question reveals some of the most important policies for conserving tropical forests. A great deal of deforestation would be avoided if markets were allowed to function more efficiently. It is because of direct government interference that the price signals are distorted, making timber extraction and, more importantly, clearance (usually by fire) for agriculture profitable. The forms taken by this interference are well established and include, in the case of Brazil[17] :

> tax credits whereby the costs of 'investment' in forest land clearance for cattle ranching can be offset against income tax;
>
> subsidized credit for crops and livestock development;
>
> the building of road infrastructure to establish political boundaries.

Equally important in the bias towards clearance is the status of land tenure. Forest dwellers frequently have no secure rights to the land, so that outsiders can readily establish rights through clearance. Indeed, in many cases, clearance of the land is a prerequisite for claiming land rights[18]. In the event of competition for rights, the agricultural colonists invariably win. Security of land tenure for indigenous peoples may be one of the most important ways of conserving tropical forests. Conferring security of tenure on colonists, however, acts like a magnet for outsiders to clear land for agriculture.

The social irrationality of forest clearance for ranching is revealed by the fact that, without subsidies, Brazilian beef cattle ranching revenues cover only about one-third of the costs of setting up the ranches, as Table 6 shows[19]. The subsidy system explains why what is privately profitable is socially unprofitable. The combined costs of tax credits, subsidised credit and the forgone timber revenues from forest destruction is estimated to have been $4.8 billion between 1966 and 1983.

Table 6

Cost Structure of Typical Beef Cattle Ranch: Brazilian Amazon

(US $ per hectare over 5 year period, 1984)

Capital Investment		(% total)
Land cost	31.7	(13.1)
Forest clearance	66.0	(27.3)
Pasture planting	26.4	
Fencing	19.4	
Cattle acquisition	90.9	(37.6)
Other	7.4	
TOTAL	241.8	(100.0)
Operating Costs		
Labour	26.2	(15.1)
Herd maintenance	21.0	
Pasture maintenance	47.3	(27.3)
Infrastructure	74.3	(42.9)
Other	4.2	
TOTAL	173.0	(100.0)
TOTAL ALL COSTS	414.8	
TOTAL REVENUES	112.5	
Revenues as % of Costs	27.1	

Source: see endnote 7

Government interference is not always a prime cause of deforestation. In Africa, for example, it is frequently government inaction that allows others to exploit forests unsustainably.

(iii) Eco-Tourism Values

Tropical forests are increasingly attracting tourists searching for adventure and/or nature appreciation. Ecotourism promises to be a major development, comparable to the existing substantial revenues earned in African countries from wildlife viewing, game drives etc. European package 'explorer' holidays to the Peruvian Amazon, for example, cost around £1500 ($2300) per person for 20 days[20]. In Costa Rica, Ecuador, Philippines and Thailand, tourism ranks among the top five industries and brings in more foreign exchange than timber and timber product exports[21]. Thus, Costa Rica earned $138 million in what was mainly nature-based tourism in 1986. Tourists arriving in Manaus, in Amazonas State, increased from 12,000 in 1983 to 70,000 in 1988. Tourism is expected to be the largest single source of income in Amazonas State in the 1990s[22]. The tourism potential of Central America and Latin America remains largely untapped[23], [24]. Self-evidently, tourism to these countries cannot all be credited to forested areas, but some unquestionably is. Additionally, tourism brings its own external costs in the form of pollution, over-exposure of wildlife to tourist vehicles, and so on.

One study suggests tentative values for tourist benefits in the Korup Forest in Cameroon[25]. On the basis of assumptions about visit rates from both tourists and researchers, annual net income to Cameroon once visitor rates have stabilised is put at £117,000 (around $180,000). Clearly, the potential for ecotourism depends on the availability of infrastructure (transport, accommodation) and thus some countries are unlikely to be able to develop this aspect of forest use.

(iv) Uses of Wild Flora and Fauna

Tropical forests act as the habitat for an enormous variety of species. Meat production from wild animals in Peru amounted to some 13,000 tonnes in 1976[26], while fish and game comprise around 80-85% of all animal protein intake in the lowland Amazon region outside of urban centres. Legal exports of hides and skins from Peru amounted to 5 million and 1/2 million respectively between 1965 and 1976[27]. The trade in live animals is significant and, sadly, non-sustainable due to excessive exploitation. As with tourism, there are frequently fine distinctions between what is and is not sustainable.

Tropical forests act as the source of genetic material for modern food crops. Cross breeding with wild varieties is essential to resist diseases and pests. One authority suggests that such cross breeding has already saved sugarcane, banana and cocoa crops from major damage[28]. Tropical forests also house many insects that are the natural enemies of plant-damaging pests, and plant chemicals that are used as insecticides. No reliable estimates of willingness to pay for tropical forest genetic material are available, and the informational needs for securing such estimates may be substantial relative to what exists in codified form[27]. Certainly, a valuation exercise should not be confused with simply looking at the value of the final product.

The valuation problem is also formidable in respect of the pharmaceutical use of tropical forest species. There is a one-in-four chance that startpoint materials for prescribed drugs have their origins in tropical forests[30]. But calculations of the market value of the prescriptions bought for such drugs is not an estimate of the value of the plant used to manufacture the drug. A number of estimates of the market value of plant-based drugs have been made[31]. But what is required is the price which drug manufacturers would be willing to pay for the plant material, plus a measure of consumers' net gains from such drugs relative to a substitute. The role of substitutes for plant-based drugs is thus crucial. Many modern drug manufacturers tend to focus more on the production of synthetic drugs using recent advances in molecular biology and biotechnology[32]. Put another way, their willingness to pay for retention of tropical forests as repositories of potential pharmaceuticals could be very low.

One study has approached the value of genetic information in the Korup Rainforest, Cameroon by assuming that the value of patents can be applied to a 'guesstimated' number of research discoveries in the forest area[33]. Assuming 10 such discoveries per year and an average patent value of £5000 ($8000), annual benefits could be £50,000 ($80,000), of which Cameroon would, of course, capture only a fraction.

5. Indirect Use Values

The ecological functions of tropical forests are many. Valuation procedures tend to be focussed on either 'damage done' or 'cost of replacement'. Thus, removal of a tropical forest that protects a watershed can result in soil erosion, downstream sedimentation, and increased floods. The damage done would then be a measure of the value of the watershed protection function since such damage would be avoided by conserving the forest. Alternatively, if the damage occurs, the expenditure on reconstituting the affected area would be a measure of the protection function. If the damage cannot be reconstituted, it may be necessary to invest in replacing the protection function. However, replacement cost approaches need to be used with caution. Implicitly, they assume it is worthwhile to make the replacement, i.e. that the benefits from replacement exceed the costs of replacement. But replacements costs are being used to value the benefits of replacement, a procedure which automatically produces benefit-cost ratios of unity.

(i) Watershed Effects

The nature and extent of losses of ecological functions from deforestation are disputed. Hamilton provides a survey of claimed watershed effects and the empirical evidence for their existence.

but others dispute Hamilton's assessment[34]. Table 7 summarises Hamilton's survey. An issue of importance is that ecological impacts depend upon the use to which deforested land is put, i.e.the nature of the agricultural system if conversion is to agriculture, the nature of the logging regime, and so on. The argument is that forests are not unique in their watershed protection functions, and hence deforestation per se does not produce adverse effects. Rather it is the nature of the succeeding land-use that matters. In theory it is perfectly possible for forest clearance to have limited or negligible watershed effects, e.g. through allowing soils to secure a cover of grasses and shrubs. In reality, the forest clearer is often the same agent that subsequently uses the forest soils in an environmentally damaging way, e.g. for cattle ranching or agriculture.

Table 7

Hamilton's Assessment of Ecological Impacts of Tropical Deforestation

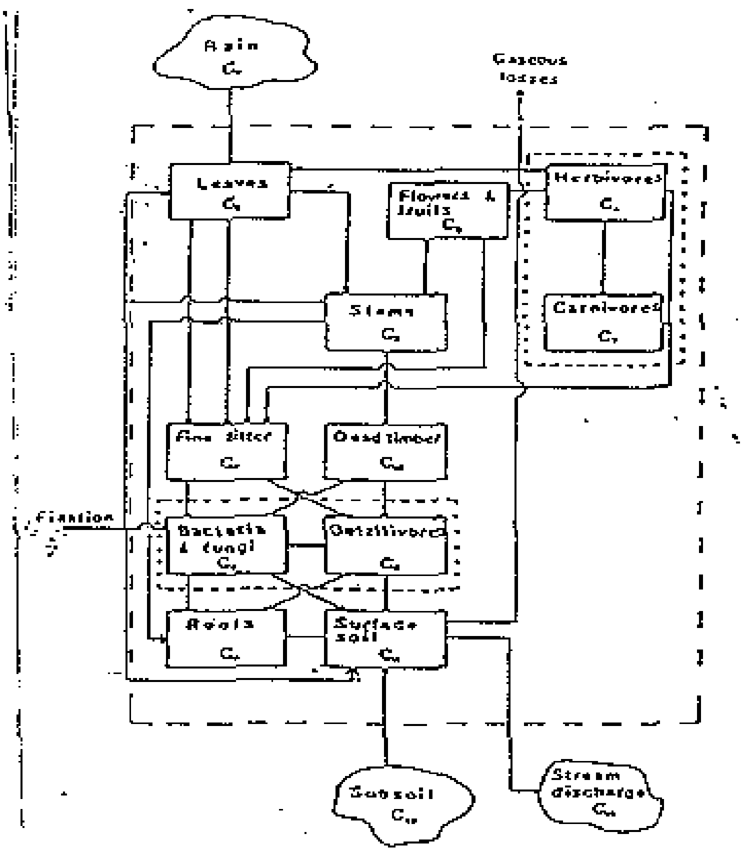
Impact		Assessment
Reduced rainfall	:	No evidence to support this claim. Possible exception of Amazon rainforest recycling[35] if permanent and large-scale deforestation occurs. Fog and cloud forests do increase rainfall.
Reduced water supplies, reduced floods	:	Claim based on idea of forests as a 'sponge' - taking in water in wet season and releasing slowly in dry season[34]. Forests more like 'pumps'. Cutting tends to increase water supply. But conversion to agriculture can lower water tables and reduce dry-season river flow.
Soil erosion and Sedimentation	:	Both effects result from conversion to agricultural systems that themselves are unstable. Traditional shifting agriculture is not implicated in such damage but modern slash-and-burn techniques ('forest farming') are unstable.

Ruitenbeek estimates the value of forest protection for inshore fisheries in the Korup region of Cameroon[37]. This comes to some £3.8 million in present value terms (at 8% discount rate). Flood control benefits are similarly estimated at £1.6 million.

(ii) <u>Nutrient Cycling</u>

Figure 1 shows a typical nutrient cycling diagram for a tropical forest. The 'Cs' refer to 'compartments' and the arrows to fluxes. The nutrients in question include calcium, magnesium and potassium which are 'bound' to soil and water, and elements such as nitrogen which are interchanged with the atmosphere. Nitrogen, phosphorus, potassium and, to some extent, calcium, are stocked in the biomass. Litterfall is thus critical in cycling these nutrients through rapid decomposition and take-up through mycorrhizal associations. The carbon and sulphur cycles are considered separately below.

FIGURE 1 NUTRIENT CYCLING IN TROPICAL FORESTS



The significance of nutrient cycling for the valuation problem is twofold. First, disturbance of the forest system releases the nutrients into aquatic systems. In tropical forests drainage water into the aquatic system is typically low in nutrients. Deforestation and, more generally, opening of the canopy, causes a nutrient outflow which itself can give rise to pollution of river and coastal ecosystems[38]. Second, and far more significant, however, the outflow of nutrients arising from deforestation means that the productive capacity of the previously forested area is seriously reduced. Forest soils are low in nutrients and this explains why cleared forest land will often sustain only limited livestock and crop production without substantial additions of artificial fertiliser. In short, 'nutrient lock-up' tends to impose an irreversibility on the spectrum of land uses subsequent to deforestation.

(iii) Carbon Cycling and the Greenhouse Effect

In the process of photosynthesis, growing forests 'fix' carbon dioxide and give off oxygen. Once grown, forests no longer accumulate carbon from the atmosphere. Mature forests are said to be in a state of (approximate) 'carbon equilibrium', i.e. they release as much CO_2 as they absorb. (The northern hemisphere's temperate and boreal forests may actually exhibit a slight net fixation of carbon, but tropical forests may safely be regarded as being in carbon equilibrium if they are mature, as would be the case for the remaining primary forest). But while the rate of carbon exchange with the atmosphere is zero for mature tropical forests, these forests 'lock-up' or 'sequester' carbon as a stock. This distinction is important since it means that deforestation will release CO_2 into the atmosphere and thus contribute to the 'greenhouse effect'. Indeed, deforestation releases other greenhouse gases such as methane. Tropical forests are major stores of carbon and hence the use made of tropical forest land, and of the timber on the land, is an important factor in global warming.

It is important to distinguish what it is that is being valued when talking of the 'carbon fixing value' of a tropical forest. The context is best viewed as one of the costs and benefits of alternative land use. Consider two basic options, to conserve tropical forest and to clear it for agriculture.

> By conserving a mature carbon-equilibrium forest, any carbon release associated with the alternative land use (agriculture) is avoided, and hence the damage associated with that carbon release is avoided. It is legitimate, then, to speak of the forest as having a 'carbon credit' equal to the avoided damage.

By clearing the forest for agriculture, deforestation occurs and carbon (and other pollutant) releases occur. The damage associated with that carbon release is therefore a 'carbon debit' to that particular forest land use.

However, it is not legitimate both to ascribe a credit to the conservation option and a debit to the clearance option. That would be double-counting since the credit and debit are the obverses of each other. Either, conservation is credited with damage avoided, or the agriculture option is debited with the damage done by deforestation.

A further complication is that the credit or debit depends on how the timber is removed, how it is subsequently used, and how the deforested land is subsequently managed[39]. Clearance by burning will be associated with a 'total' release of CO_2, i.e. there are no offsetting credits in terms of the use made of the timber. But if the land is subsequently managed in such a way that carbon is once again fixed, for example by grassland, then that rate of fixation has to be offset against the loss of carbon from deforestation. Typically, forests contain 20-100 times more carbon per unit of area than agricultural lands. Thus the offset due to subsequent land use will be far from sufficient to offset totally the loss from deforestation through clearance. The same goes for any 'downstream' reappearance of carbon: by far the greater part of released carbon goes into the atmosphere.

If the forest is clear-felled and all the timber is used to make long-lived wood products (housing timbers, furniture, for example) then the act of deforestation may cause very little carbon release because the carbon remains 'locked up' in the timber products. This is 'product carbon offset'. Subsequent land-use may then fix some carbon, so that the overall effect of deforestation on carbon release could be very small, zero, or even, possibly, negative. This second kind of offset is 'land use carbon offset'.

In fact, taking a global view, most deforestation occurs through direct clearance or incidental damage. The early 1980 estimates of deforestation suggested that some 11.1 m.h.p.a of tropical forest were being lost. Of this, 7.3 m.h.p.a were being cleared directly for agriculture, usually by burning, and a further 3.8 m.h.p.a. were cleared for some combination of agriculture and fuelwood. Selective logging took place on a further 4.4 m.h.p.a and, while selective logging is, in principle, consistent with regeneration (and hence little change in the carbon store over time) in practice it tends to be associated with extensive damage to the remaining tree stocks and hence produces carbon release[40]. While the extent of net carbon release will be location-specific, in terms of the overall rate of deforestation it is fair to suggest that there is little 'product carbon offset' to the carbon releases caused by deforestation. Both the 'land-use offset' and the 'product offset' tend to be allowed for in the better studies of carbon release[41].

Taking the various offsets into account, carbon emissions for 1980 due to deforestation have been estimated to lie somewhere in the range 0.4 - 2.5 x 10^{15}g, i.e. 0.4 - 2.5 gigatonnes p.a. (10^{15} g = 1 billion metric tonnes = 1 gigatonne) [42], with a mean figure of 1.8 gigatonnes p.a. This compares with fossil fuel CO_2 releases of 5.3 gigatonnes in 1984. Of this total of 7.1 gigatonnes around half remains in the atmosphere, the rest being absorbed by the oceans and other sinks, making a net accretion of some 3.6 gigatonnes in the atmosphere. Tropical deforestation may therefore be contributing about 25 per cent of CO_2 emissions which, in turn, contribute perhaps half of the total greenhouse gases. Tropical deforestation would therefore contribute some 10-13 per cent of all greenhouse gas emissions.

More recent estimates suggest that rates of deforestation have increased (see above Section....), and carbon released could be some 2 - 3 gigatonnes p.a.[43].

Two issues arise: (a) what 'carbon credit' should be given to tropical forests for their contribution to avoiding the global warming impacts of deforestation, i.e. what is the carbon credit to conservation and hence the carbon debit to clearance, and (b) what contribution could <u>afforestation</u> make to containing the greenhouse effect ?

(iii - a) <u>Carbon Credits</u>

In line with the 'damage avoided' approach to valuation, a tropical forest should be credited with the value of global warming damage avoided by its conservation. Some monetary estimates of global warming damage exist, and they suggest that the damage done, mainly in terms of sea-level rise, could be some $13 per tonne of carbon[44].

Table 8 shows some recent estimates of rates of deforestation and the resulting carbon releases for a single year, 1989. Most of the carbon release from deforestation occurs in the first five years. Focussing on a single year therefore understates the total carbon loss since release occurs beyond the single year. But the analysis helps to illustrate the orders of magnitude of cost involved.

Table 8

Deforestation Rates and Carbon Release, 1989

Country	Rate of Deforestation (million ha)	Carbon Release (m.t.C)	Carbon Release/ Deforestation (tC/ha)
Brazil	5.0	454	90.8
Indonesia	1.2	124	103.3
Vietnam	0.35	36	102.9
Bolivia	0.15	14	93.3
Guyanas	0.05	4	80.0
34 Countries	13.86	1,398	100.9

Source: adapted from R.Houghton, 'Emissions of Greenhouse Gases', in N.Myers, Deforestation Rates in Tropical Forests and Their Climatic Implications, Friends of the Earth, London, 1990.

Table 8 indicates that, on average, deforestation of one hectare of land contributes some 100 tonnes carbon to the atmosphere in a single year. At some $13 per tonne damage, it follows that deforestation causes damage at a rate of some $1300 per hectare. In reality, the damage is higher than this because of the fact that carbon release continues after one year.

(iii - b) The Carbon Value of Afforestation

Sedjo has suggested that one hectare of new forest on good sites in the Pacific Northwest and southern United States could sequester some 6×10^6 g C p.a.(6 tonnes)[45]. If, hypothetically, afforestation programmes were designed to take up, say, 3 gigatonnes of the 3.6 gigatonnes net accretion of carbon, then some 470 million hectares of new plantation would be needed, or around 10 per cent of the current area of forest in the world. Given the obvious problems of such a massive land - take for forestry, effort might be better devoted to raising existing standing crop biomass. The figures suggest that it would be necessary to raise crop biomass by 50 per cent.

Myers suggests that a working mean sequestration rate of 10 tonnes of carbon per hectare per annum is appropriate for tropical forests[46], making the required hectarage of afforestation around some 300 million hectares. At 10 tonnes per hectare per annum, the carbon credit would be some $130 per hectare per annum.

(iv) Sulphur Cycling

The nature of sulphur cycling in tropical forests appears to be imperfectly understood. Some authorities have suggested that tropical forests contribute to acid rain[47]. Others regard tropical forests as net 'scrubbers' of sulphur.

Conclusions on Indirect Use Value

There is uncertainty about the nature of tropical forest ecological functions. But it seems clear that the forests generate positive economic value in this respect. Moreover, given the uncertainty it is inconsistent with risk-averse behaviour to deforest. For deforestation of closed canopy primary forest is effectively irreversible. It is a long process to re-establish climax systems. In that respect rational behaviour under uncertainty would dictate a very cautious attitude to deforestation.

6. Non-Use Benefits: Existence Value

The final category of value is non-use value, the value attached to tropical forests simply to ensure that they exist. The motivations for existence value need not concern us unduly[48]. Efforts to estimate existence value are based on contingent valuation studies which essentially use a 'willingness to pay' questionnaire approach. No study has been carried out for tropical forests, but Table 9 reports estimates of average annual values per person taken from contingent valuation studies for selected animal species and natural amenities. While the studies are limited in number, there is a consistency about the values. The animal values cluster in the $5-8 range, with American national symbols - the grizzly bear and the bald eagle -in the $10-15 range. The Grand Canyon similarly has a high valuation as a piece of major national heritage, compared to the value of cleaning up a river.

Could such values be 'borrowed' for tropical forests ? They are unique assets, but they are (generally) in countries other than rich nations. Allowing for this 'distance' between valuer and the object of value (which applies to the blue whale as well), and the substantial worldwide interest in tropical deforestation, a figure of $8 per adult per annum would seem very conservative. Allowing for valuations by just the richest nations of the world with some 400 million adults (Western Europe, North America, Australasia), the valuation would be some $3.2 billion p.a.

The opportunity cost of forest conservation is the 'development' benefits forgone. As we have seen, these may not in fact be greater than the benefits of sustainable use of tropical forests. But in order to assess the back-of-the-envelope guesstimate of existence value, one might look at the developmental uses of tropical forests to see what benefits accrue. If we take Amazonia as an example, the entire GNP of 'classical' Amazonia is about 6 per cent of Brazil's GNP. In 1986 Brazil's GNP was some $200 billion. Thus Amazonia contributed around $12 billion. On the assumption that each adult person in wealthy countries of

Table 9

Non-Use Values for Unique Natural Assets

Asset:	Value per Adult ($ mid 1980s)
Animal Species	
Bald eagle	11
Emerald shiner	4
Grizzly bear	15
Bighorn sheep	7
Whooping crane	1
Blue whale	8
Bottlenose dolphin	6
California sea otter	7
Northern elephant seal	7
Natural Amenities	
Water quality (S.Platte river basin)	4
Visibility (Grand Canyon)	22

Source: [47]

the world would be willing to contribute $8 p.a. to an 'Amazon Conservation Fund', the resulting $3.2 billion would enable the people responsible for more than 25% of the economic output of Amazonia to be compensated for ceasing their activities.

7. Conclusions

The concept of total economic value offers a comprehensive framework within which to value tropical forests. Total economic value comprises use values, option values and existence values. Direct use values include timber and non-timber products and ecotourism. Indirect use values include the ecological functions of tropical forests: their watershed protection and mineral cycling functions. Existence value relates to the value of the forest 'in itself', unrelated to any use. All these values are 'of' people. The total economic value approach is totally anthropomorphic. It does not deny other rationales for conserving tropical forests based on 'rights' in nature. Yet it may not be necessary to resort to such moral arguments. Economic arguments alone could well be sufficient to justify a dramatic reduction in deforestation.

There is some evidence that use values alone favour forest conservation. Clearance for livestock agriculture in particular appears to have no financial rationale. Its existence depends on substantial subsidies which themselves introduce major economic distortions. Alternative uses to timber, based on minor forest products, appear to give higher financial rates of return than timber in some areas. Markets fail to allocate forests to their 'best' uses because of inefficiency in government intervention, notably subsidisation and the absence of secure tenure for small farmers. The recreational use of tropical forests is only now beginning to be realised.

Indirect use values must be estimated. As yet, little effort has been made to value these indirect functions. As we have seen, some of them are disputed, but there is no question that deforestation followed by unsuitable land use causes significant damage. Additionally, tropical forests should be given 'carbon credits' for their role in containing the greenhouse effect. For existing forests the credit would relate to avoided damage by not developing, i.e the benefit of conservation. This might total some $1000 per hectare for a single year, with perhaps similar benefits about 5 years. For new forests, values might be of the order of $130 per hectare per annum.

Existence values could be substantial and might easily dominate the use and indirect values. That would be consistent with other findings in the total economic valuation literature. On the assumption that the Amazon forest is valued at an average of $8 per adult in the advanced economies of the world (only), existence value could readily amount to $3 billion, or a quarter of the entire GDP contribution of classic Amazonia to Brazil's GDP, inclusive of mineral extraction, timber and agriculture.

EndNotes

1. 'Economic' is not to be confused with 'financial' or 'commercial'. Anything contributing to human welfare is deemed to be an economic function, and the flow of services may or may not have a cash flow associated with it. In the case of tropical forests most functions do not have evident cash flows.

2. See D.W.Pearce, 'Economic Incentives and Renewable Natural Resource Management', in OECD, Renewable Natural Resources: Economic Incentives for Improved Management, OECD, Paris, 1989, 11-27; and D.W.Pearce and R.K.Turner, Economics of Natural Resources and the Environment, Harvester-Wheatsheaf, London and Johns Hopkins U.P., Baltimore, 1989, ch. 20.

3. The literature on option value is extensive. See R.C.Bishop, 'Option Value: an Exposition and Extension', Land Economics, 58, No.1, 1982, 1-15; A.M.Freeman, 'Supply Uncertainty, Option Price and Option Value', Land Economics, 61, 1985, 176-181; M.Plummer, 'Supply Uncertainty, Option Price and Option Value', Land Economics, 62, 1986, 313-18; P-O Johansson, 'On the Properties of Supply-Side Option Value', Land Economics, 64, 1988, 86-87; R.C.Bishop, 'Option Value: Reply', Land Economics, 64, 1988, 88-93. The sign of option value is indeterminate but may be expected to be positive if the future demand for the asset in question (the tropical forest function in this case) is certain, and the supply is uncertain.

4. See, C.Henry, 'Option Values in the Economics of Irreplaceable Resources', Review of Economic Studies, 1974, 89-104; and A.C.Fisher and M.Hanemann, 'Quasi Option Value: Some Misconceptions Dispelled', Journal of Environmental Economics and Management, 14, 1987, 183-190.

5. See D.Brookshire, L.Eubanks and A.Randall, 'Estimating Option Prices and Existence Values for Wildlife Resources', Land Economics, 59, 1983, 1-15; D.Brookshire, W.Schulze, M.Thayer, 'Some Unusual Aspects of Valuing a Unique Natural Resource', Department of Economics, University of Wyoming, 1985; W.Schulze, 'Economic Benefits of Preserving Visibility in the National Parklands of the Southwest', Natural Resources Journal, 23, 1983, 149-173.

6. See A.J.Leslie, 'A Second Look at the Economics of Natural Management Systems in Tropical Mixed Forests', Unasylva, Vol.39, No.155, 1987, 46-58.

7. A detailed survey of tropical moist forest management systems concluded that only one-tenth of one per cent of the 828 million hectares of productive forest is under sustained-yield

management. See D.Poore, No Timber Without Trees: Sustainability in the Tropical Forest, Earthscan, London, 1989, chapter 7.

8. For the view that sustained forest management should be based on clear-cutting and the maximisation of biomass use, see G.Hartshorn, R.Simeone, J.Tosi, 'Sustained Yield Management of Tropical Forests: A Synopsis of the Palcazu Development Project in the Central Selva of the Peruvian Amazon', Tropical Science Center, San Jose, Costa Rica, 1987. The analysis tends to assume that market conditions are right, i.e. that timber production takes place near to markets.

9. These figures are taken from D.W.Pearce, Forest Policy in Indonesia, Memorandum, World Bank, December 4, 1987. The base data comes from R.Sedjo, The Economics of Natural and Plantation Forests in Indonesia, Resources for the Future, Washington DC, August 1987, mimeo; and R.Sedjo, Incentives and Distortions in Indonesian Forest Policy, Resources for the Future, Washington DC, October 1987, mimeo. The NPVs include revenues from the initial harvest of the standing stock.

10. Leslie, op.cit. suggests that shadow pricing will favour the more natural management systems.

11. See A.Markandya and D.W.Pearce, Environmental Considerations and the Choice of Discount Rate in Developing Countries, World Bank, Environment Department, Working Paper No.3, May 1988, World Bank, Washington DC.

12. See D.W.Pearce, E.Barbier and A.Markandya, Sustainable Development: Economics and Environment in the Third World, Edward Elgar, London, 1990, chapter 5.

13. J.de Beer and M.McDermott, 'The Economic Value of Non-Timber Forest Products in South-East Asia', International Union for the Conservation of Nature, Netherlands Commitee, Amsterdam, 1989.

14. See N.Myers, 'Tropical Moist Forests: Over-Exploited and Under-Utilized?', Forest Ecology and Management, Vol.6, 1983, 59-79.

15. We are indebted to Simon Rietbergen for this point.

16. See C.Peters, A.Gentry, R.Mendelsohn, 'Valuation of an Amazonian Rainforest', Nature, Vol.339, June 29, 1989, 655-656.

17. See D.Mahar, Government Policies and Deforestation in Brazil's Amazon Region, World Bank, Washington DC, 1989; H.Binswanger, Brazilian Policies That Encourage Deforestation in the Amazon, Environment Department, World Bank, Working Paper No.16, Washington DC, April 1989; R.Repetto and M.Gillis (eds), Public Policies and the Misuse of Forest Resources, Cambridge

University Press, Cambridge, 1988.

18. See D.Southgate, R.Sierra and L.Brown, The Causes of Tropical Deforestation in Ecuador: a Statistical Analysis, London Environmental Economics Centre, LEEC Paper 89-09, 1989.

19. See J.Browder, 'The Social Costs of rain Forest Destruction: a Critique and Economic Analysis of the 'Hamburger Debate'', Interciencia, Vol.13, No.2, 1988; and J.Browder, 'Public Policy and Deforestation in the Brazilian Amazon', in R.Repetto and M.Gillis (eds), Public Policies and the Misuse of Forest Resources, Cambridge University press, Cambridge, 1988, 247-297.

20. One company advertises a tour with a two-day excursion into Amazonia, the excursion costing $250 extra on a basic charge of $2300. As a very rough guide, therefore, each 'visitor day' could be worth $125 as a gross value, and less as value-added.

21. See J.Gradwohl and R.Greenberg, Saving the Tropical Forests, Earthscan, London, 1988, pp.66-7.

22. Quoted in P.Dogse, Sustainable Tropical Rain Forest Management: Some Economic Considerations, Paper prepared for the Division of Ecological Sciences, UNESCO, Paris, October 1989.

23. See H.J.Leonard, Natural Resources and Economic Development in Central America, Transaction Books, New Brunswick, 1987.

24. See M.J.Dourojeanni, 'Over-Exploited and Under-Used Animals in the Amazon Region', in G.Prance and T.Lovejoy (eds), Key Environments: Amazonia, Pergamon, Oxford, 1985, 419-33.

25. J.Ruitenbeek, Social Cost-Benefit Analysis of the Korup Project, Cameroon, World Wide Fund for Nature, London, September 1989.

26. Dourojeanni, op.cit, p.420.

27. Dourojeanni, op.cit. p.423.

28. N.Myers, 'Tropical Moist Forests: Over-Exploited and Under-Utilized?', Forest Ecology and Management, Vol.6, 1983, 59-79.

29. See G.Brown, 'Preserving Endangered Species and Other Biological Resources', The Science of the Total Environment, Vol.56, 1986, 89-97.

30. N.Farnsworth and R.Morris, 'Higher Plants - the Sleeping Giant of Drug Development', American Journal of Pharmacy, vol.147, No.2, 1976, 46-52.

31. Notably, N.Farnsworth and D. Soejarto, 'Potential Consequence of Plant Extinction in the United States on the Current and Future Availability of Prescription Drugs', Economic Botany, Vol.39, No.3, 1985, 231-240. A figure of some $8 billion is quoted as the value of prescribed plant-based drugs for the USA. Principe calculates a figure for all OECD countries of $43 billion in 1985, including over-the-counter drugs. See P.Principe, The Economic Value of Biological Diversity Among Medicinal Plants, OECD, Paris, 1987.

32. See P.Principe, The Economic Value of Biological Diversity Among Medicinal Plants, OECD, Paris, 1987.

33. J.Ruitenbeek, Social cost-Benefit Analysis of the Korup Project, Cameroon, World Wide Fund for Nature, London, September 1989.

34. L. Hamilton and P. King, Tropical Forested Watersheds: Hydrologic and Soils Response to Major Uses or Conversions, Westview Press, Boulder, 1983. For a contrasting view see N.Myers, 'Tropical Moist Forests: Over-Exploited and Under-Utilized' ?, Forest Ecology and Management, 6, 1983, 59-79.

35. See E.Salati et al., 'Recycling of Water in the Amazon Basin: an Isotopic Study', Water Resources Research, 15, 1979, 1250-1258.

36. Myers, op.cit. espouses the sponge analogy.

37. Ruitenbeek, op.cit.

38. See J.I.Furtado and K.Ruddle, 'The Future of Tropical Forests', in N.Polunin (ed), Ecosystem Theory and Application, Wiley, 1986, 145-171; J.I.Furtado, 'The Status and Future of the Tropical Moist Forest in Southeast Asia', in C.MacAndrews and L.S.Chia (eds), Developing Economies in South East Asia and the Environment, McGraw Hill, Singapore, 1978, 73-119.

39. We are indebted to Jack Ruitenbeek for assistance in clarifying the argument in this section. Much of the literature on the 'carbon value' of tropical forests is misleading in that it fails to take account of (a) uses of the timber culled from deforestation, and (b) the subsequent land use. For an exercise in calculating carbon credits for temperate forests see D.W.Pearce, 'Assessing the Returns to the Economy and to Society from Investment in Forestry', in (UK) Forestry Commission, Forestry Expansion, Edinburgh, 1990.

40.. See World Resources Institute, World Resources 1988-1989, Basic Books, New York, p.71; and R.Repetto, 'Deforestation in the Tropics', Scientific American, Vol.262, No.4, April 1990, pp.36-42.

41. E.g. Houghton, op.cit.

42. R.Houghton et al., 'Net Flux of Carbon Dioxide From Tropical Forests in 1980', Nature, 316, 15 August 1985, 617-620; and R.Houghton, 'The Future Role of Tropical Forests in Affecting the Carbon Dioxide Concentration of the Atmosphere', Ambio, Vol.19, No.4, July 1990.

43. R.Houghton, 'The Future Role of Tropical Forests in Affecting the Carbon Dioxide Concentration of the Atmosphere', Ambio, Vol.19, No.4, July 1990, pp. 204-209.

44. See W.Nordhaus, 'To Slow or Not to Slow: The Economics of the Greenhouse Effect', Department of Economics, Yale University, 1990, mimeo. The figures are in 1989 dollars.

45. R.Sedjo, 'Forests to Offset the Greenhouse Effect', Journal of Forestry, 87, 1989, 12-14.

46. N.Myers, 'The Greenhouse Effect: a Tropical Forestry Response', Biomass, 18, 1989, .

47. H.L.Clark et al., 'Acid Rain in the Venezuelan Amazon', in J.I.Furtado (ed), Tropical Ecology and Development, ..., Kuala Lumpur, 1980, 683-685. See also R.Herrera, 'Nutrient Cycling in Amazonian Forests', in G.Prance and T.Lovejoy, key Environments: Amazonia, Pergamon, Oxford, 1985, 95-105.

48. Although some economists express a concern that such valuations may be 'counter-preferential', i.e. inconsistent with individuals' preferences in the same way that acts of duty or obligation are counter-preferential. If so, there may be implications for the underlying structure of the welfare economics used to evaluate 'resource worth'. See D.Brookshire, L.Eubanks, C.Sorg, 'Existence Values and Normative Economics: Implications for Valuing Water Resources', Water Resources Research, Vol.22, No.11, 1986, 1509-1518.

49. Taken from K.Samples, M.Gowen, J.Dixon, 'The Validity of the Contingent Valuation Method for Estimating Non-Use Components of Preservation Values for Unique Natural Resources', Paper presented to the American Agricultural Economics Association, Reno, Nevada, July 1986.

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BOOKS

Edward B Barbier,

Economics, Natural-Resource Scarcity and Development: Conventional and Alternative Views. Earthscan Publications Limited, London, 1989. Paperback - £15

The history of environmental and resource economics is reviewd, then using insights provided by environmentalism, ecology and thermodynamics, Barbier begins the construction of a new economic approach to the use of natural resources and particularly to the problem of environmental degradation. With examples from the global greenhouse effect, Amazonian deforestation and upland *degradation on Java, Barbier develops a major theoretical advance and shows how it can be applied. This book breaks new ground in the search for an economics of sustainable developement.*

David W Pearce, Edward B Barbier and Anil Markandya,
<u>Sustainable Development: Economics and Environment in the Third World</u>, Edward Elgar Publishing Limited, London 1989.

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The authors attempt to give some structure to the concept of sustainable development and to illustrate ways in which environmental economics can be applied to the developing world. Beginning with an overview of the sustainable development concept, the authors indicate its implications for discounting and economic appraisal. Core studies on natural resource management are drawn from Indonesia, Sudan, Botswana, Nepal and the Amazon.

David W Pearce, Anil Markandya and Edward B Barbier
<u>Blueprint for a Green Economy</u>, Earthscan, September 1989, £6.95 (third printing)

This book by the London Environmental Economics Centre was prepared as a report for the Department of Environment, as a follow up to the UK government's response to the Brundtland Report. Here it stated that: '...the UK fully intends to continue building on this approach (environmental improvement) and further to develop policies consistent with the concept of sustainable development.'
The book attempts to assist that process.

Gordon R. Conway and Edward B. Barbier
<u>After the Green Revolution: Sustainable Agriculture for Development</u>
Earthscan, London 1990 £8.95

The Green Revolution has been successful in greatly improving agricultural productivity in many parts of the developing world. But these successes may be limited to specific favourable agro-ecological and economic conditions. This book discusses how more sustainable and equitable forms of agricultural development need to be promoted. The key is developing appropriate techniques and participatory approaches at the local level, advocating complementary policy reforms at the national level and working within the constraints imposed by the international economic system.

David W. Pearce and R. Kerry Turner
** *Economics of Natural Resources and the Environment*, Harvester-Wheatsheaf, London and Johns Hopkins University Press, Baltimore, 1989.

This is a major textbook covering the elements of environmental economics in theory and practice. It is aimed at undergraduates and inlcudes chapters on sustainable development, environmental ethics, pollution taxes and permits, environmental policy in the West and East, recycling, and optimal resource use.

Edward B. Barbier, Joanne C. Burgess, Timothy M. Swanson and David W. Pearce
Elephants, Economics and Ivory, Earthscan, November 1990. £8.95

The dramatic decline in elephant numbers in most of Africa has been largely attributed to the illegal harvesting of ivory. The recent decision to ban all trade in ivory is intended to save the elephant. This book examines the ivory trade, its regulation and its implications for elephant management from a truly economic perspective. The authors'preferred option is for a very limited trade in ivory, designed to maintain the incentive for sustainable management in the southern African countries and to encourage other countries to follow suit.

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The London Environmental Economics Centre (LEEC) is now known as the Environmental Economics Programme, at the International Institute for Environment and Development. The former name dates from 1987 when the Centre was established by IIED and the Economics Department of University College, London.

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