COMMENTARY

The Economic Value of Forest Ecosystems

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ABSTRACT

Forest ecosystems are being degraded and lost because of rapid population change and economic incentives that make forest conversion appear more profitable than forest conservation. All ecological functions of forests are also economic functions. Many important forest functions have no markets, and hence, no apparent economic value, justifying the use of forest land for other purposes. Imputing economic values to nonmarketed benefits has the potential to change radically the way we look at all forests and to make the pendulum swing back from a presumption in favor of forest conversion to more conservation and sustainable use. This paper surveys what we know about forest economic values and draws policy conclusions from the now substantial literature that values nonmarket benefits of forests. Estimating economic values is not enough. The subsequent stage of policy is to design markets that capture the values—'market creation'—ideally for the benefit of the many vulnerable communities that rely on the forests for their well-being. These conclusions support the wider argument for using effective economic instruments to promote conservation of the remaining forests. Forest loss involves: risks to human health; accelerated climate change; increased watershed disruption, adding to eutrophication in inland and coastal waters; loss of water quality; and loss of biodiversity.

INTRODUCTION: THE ISSUE

Forest ecosystems are under threat. Rates of net deforestation (deforestation minus afforestation) are disputed. The Food and Agriculture Organization (FAO 2001) estimates annual global net rates of deforestation of around 9 million hectares in the 1990s, or 0.23% of total forest area. The World Resources Institute (Matthews 2001) disputes that figure, noting that FAO data include biodiversity-poor plantations as afforestation, offsetting natural forest loss. Net of plantation growth, annual losses are closer to 16 million hectares per annum, or 0.4% per annum of forest cover, nearly double the FAO figure. Whatever the right figure, forest loss is a long-term process that reflect the growth of land occupation by humankind and the systematic conversion of forest land to agriculture (Richards 1990). Nonetheless, substantial opinion regards this process as one that now imposes risks to ecological resilience and human well-being. If these risks are real, it is vital to understand the forces at work that generate deforestation. Without an understanding of true causes, effective policy cannot be designed.

The reality is that the causal factors are complex and varied. They include population change and the consequent demand for land for food production. But environmental economists have long drawn attention to two other factors that, together, probably account for the greater part of forest loss. Both factors are embedded in a single notion: economic incentives. In the first place, many governments provide financial incentives to convert forest land. Many forms of subsidy, explicit and hidden, encourage inefficient logging and agricultural colonization. In turn, while a few of the subsidies are designed to help vulnerable groups in society, most favor middle and rich classes as forms of 'rent' that can then be captured by rent seekers—individuals concerned with maximizing their share of financial revenues in return for political and other favors. Thus, the

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scale of illegal logging is unknown but is clearly very large relative to designated logging areas (Contreras-Hermosilla 2001). The second form of incentive arises because many of the ecological functions of forests are unmarketed, generating the illusion that, because their price is zero, so is their economic value. When conservation competes with conversion, conversion wins because its values have markets, whereas conservation values appear to be low or zero. In the absence of markets in carbon dioxide (CO_2) reduction, for example, carbon stored in forests has a zero price. But its economic value is substantial because, released as CO_2, it causes considerable economic damage via climate change impacts. Prices and values should not, therefore, be confused. In turn, economic damage is defined as any loss of human well-being now or in the future. There need be no corresponding financial flows, but if there are, then markets are likely to respond to the resulting prices.

This focus on incentives is the basic justification for the process of 'demonstration and capture' of economic values. First, the economic value of forest functions in nonmarket contexts has to be estimated. Second, the resulting values need to be 'internalized' in market (or regulatory) systems so that they affect land use decisions. To some extent, this is already happening. Downstream farmers are paying upstream forest owners to conserve their forests in order to protect water supplies. Other farmers pay forest owners to conserve forests as windbreaks and regulators of microclimate for crop productivity. There are now several hundred 'carbon deals' whereby companies and governments pay for forest conservation, collecting a paper credit for the CO_2 that is not released. These credits currently function as a sign of 'green credibility,' but they will also operate as tradable credits within the Kyoto Protocol 'flexibility mechanisms.' Increasingly, then, forest values are being marketed. While many still feel a sense of unease at this 'commercialization' of nonmarket environmental services, there are at least two powerful reasons for encouraging it. First, it addresses directly the forces that generate deforestation. Second, the history of efforts at global forest conservation to date is not encouraging. Something new is needed.

This paper focuses on the first part of the demonstration-capture paradigm. Space forbids addressing the design of capture mechanisms. We ask, just how much are forest ecosystems worth in economic terms?

FOREST GOODS AND SERVICES

Forests worldwide generate a substantial number of goods and services that benefit humankind. The measure of economic value that is relevant is individuals' willingness to pay for those benefits. These values might be conveniently classified as:

- direct use values: values arising from consumptive and nonconsumptive uses of the forest, e.g., timber and fuel, extraction of genetic material, tourism;
- indirect use values: values arising from various forest services, such as protection of watersheds and the storage of carbon;
- option values: values reflecting a willingness to pay to conserve the option of making use of the forest even though no current use is made of it;
- nonuse values (also known as existence or passive use values): these values reflect a willingness to pay for the forest in a conserved or sustainable use state, but the willingness to pay is unrelated to current or planned use of the forest.

Use and nonuse values are all capable of being measured in monetary terms. In practice, there is limited evidence on some of the values and considerable evidence on others. Economic valuation studies have also tended to concentrate on a limited number of areas.

DIRECT USE VALUES

TIMBER VALUES

Two types of timber use need to be distinguished: commercial and noncommercial. Local uses may be commercial or can relate to subsistence, e.g., building poles. World industrial roundwood production expanded substantially between 1960 and 1990 from some 1 billion m^3 to 1.6 billion m^3 but has since fallen back to some 1.5 billion m^3 in the late 1990s (Barbier *et al.* 1994; FAO 2001). Tropical woods production accounts for around 40% of total roundwood production, and tropical woods exports account for 25% of world production (Barbier *et al.* 1994). Since timber is marketed, its economic value should be easy to derive. In practice, there are problems in determining this value. First, the 'ex forest' price of a log refers to the price received on sale to a processor or an exporter, and the costs of extraction and transportation need to be deducted. It is not easy to find reliable estimates of such costs. In turn, the 'value of the timber stand'—its 'stumpage value'—is given by the maximum that a concessionaire should be willing to pay for the concession. Estimates of stumpage value are also difficult to find. No estimates of the total financial value of world timber output appear to be available.

In a comprehensive survey of sustainable forestry practice, Pearce *et al.* (2001, 2002) find that *sustainable* forest management is less *profitable* than *nonsustainable* forestry, although definitional problems abound. Profit here refers only to the returns to a logging regime. They do not include the other values of the forest. Sustainable timber management can be profitable, but conventional (unsustainable) logging is more profitable. This result is hardly surprising given the role that discount rates play in determining the profitability of forestry. The higher the discount rate, the less market value is attached now to yields in the future. If logging can take place in natural forests with maximum harvest now, this will generate more near-term revenues than sustainable timber practice. Similarly, sustainable timber management involves higher costs, e.g., in avoiding damage to standing but noncommercial trees. The significance of the general result is that the nontimber benefits, including ecological and other services, from sustainable forests must exceed the general loss of profit relative to conventional logging for the market to favor sustainable forestry.

FUELWOOD AND CHARCOAL

FAO (2001) statistics suggest that some 1.86 billion m^3 of wood is extracted from forests for fuelwood and conversion to charcoal. Of this total, roughly one half comes from Asia 28% from Africa 10% from South America, 8% from North and Central America, and 4% from Europe. All sources agree that fuelwood is of major importance for poorer countries and for the poor within those countries. While fuelwood may be taken from major forests, much of it comes from woodlots and other less concentrated sources. Extraction rates may or may not be sustainable, depending on geographic region. Hardly any fuelwood and charcoal is traded internationally.

OTHER NONTIMBER FOREST PRODUCTS (NTFPs)

NTFP extraction may be sustainable or nonsustainable and few studies make observations as to which is the case. Extractive uses include: taking wild animals for food (hunting), taking animals, fish, crustaceans, and birds for local or international trade or for subsistence use, and taking tree products such as latex, wild cocoa, honey, gums, nuts, fruits and flowers/seeds, spices, plant material for local medicines, rattan, fodder for animals, fungi, and berries. An extensive survey of these values can be found in Pearce & Pearce (2001). The values suggest a clustering of NTFP net values of a few dollars per hectare per annum up to around $100 (all monetary values in this paper are reported in U.S. dollars). However, these values cannot be extrapolated to all forests. Typically, the higher values relate to readily accessible forests and values for nonaccessible forests would be close to zero in net terms due to the costs of access and extraction.

The social importance of NTFPs is not necessarily captured by the economic value per hectare of forest. This is because the benefits of NTFPs accrue mainly to local communities. The size of the population base making use of the forests may, therefore, be comparatively small, and the implied value per hectare may, therefore, also be small due to the unit values being multiplied by a comparatively small number of households. For this reason, it is important to discern, as far as possible, what the values of the NTFPs are as a percentage of household incomes. Table 1 shows some results. This perspective again demonstrates the critical importance of NTFPs as a means of income support. Indeed, it underlines (A) the need to ensure that measurements of household income include the nonmarketed products taken 'from the wild' and (B) the role that NTFPs play in poverty alleviation.

BIODIVERSITY AND GENETIC INFORMATION

Taking species richness as one measure of diversity, species richness increases from the poles to the equator. For example, tropical forests probably contain more than half the world's species. Patterns vary according to whether the indicator relates to mammals, insects, plants, etc. Islands have a critical role to play, often containing high species endemism. The economic value of this diversity is the subject of a rapidly growing literature, but one that remains very unsatisfactory in terms of the reporting of values for forest types. The essence of the value of diversity is that it embodies the value of *information* and *insurance*. Ex-

TABLE 1

NTFPs as percentages of total household income

Study	Site	NTFPs as % household income
Lynam *et al.* 1994	Zimbabwe:	
	Chivi	40–160
	Mangwende	12–47
Houghton & Mendelsohn 1996	Middle Hills, Nepal	Fodder, fuel, and timber can yield as much net revenue as agriculture
Kramer *et al.* 1995	Mantandia, Madagascar	47 (lost forest products as % of household output)
Bahuguna 2000	Madhya Pradesh, Orissa and Gujarat, India	49 (fuelwood and fodder = 31%, 10% employment, 6% other NTFPs, 2% timber and bamboo)
Cavendish 1999	Zimbabwe	35% (across many different environmental goods)

isting diversity is the result of evolutionary processes over several billion years. Hence, existing diversity embodies a stock of information, and, because the evolutionary process has occurred in the context of many different environmental conditions, the diversity of living things also embodies characteristics that make them resilient to further 'natural' change (but not to human intervention). In essence, the existing stock of diversity exists to protect the entire range of goods and services, including information, provided by the diverse system. The true extent of this information is unknown and will only be revealed through further research. Economic analysis now emphasizes the value of information secured from delaying decisions that have irreversible consequences in a context of uncertainty about the values that are lost—exactly the forest loss context (Dixit & Pindyck 1994; Fisher 2000). Work is only now just beginning to emerge that approaches this issue.

There is a debate about the information functions of diversity as they relate to drugs and crop breeding. The more unique the information is, the more valuable it is, so that the existence of substitutes is a critical factor affecting the economic value of the information. This has affected efforts to value the information content in several ways. First, while forest degradation continues, it can be argued that the remaining stock is so large that willingness to pay to conserve part of the stock is currently small. Second, the willingness to pay will be small as long as there are substitutes, and this is true of both agricultural germplasm and 'medicinal' germplasm. Also relevant is the fact that research and development efforts are more easily diverted to genetic manipulation than to the identification of 'wild' genetic information.

Swanson (1997) reports the results of a survey of plant-breeding companies, finding that the sampled companies rely on germplasm from relatively unknown species for 6.5% of their research (i.e., on *in situ* and *ex situ* wild species and landraces). This percentage appears small compared to the more than 80% of research relying on commercial cultivars. But, expressing the 6.5% as a percentage of the 82.9% well-understood and standardized material, suggests that the stock of germplasm within the agricultural system tends to depreciate at a rate of 8% of the material currently in the system. Put another way, this 8% 'injection' of the relatively unknown species is required just to maintain the system as it is. But the 8% comes from a stock of natural assets—biodiversity—that is itself eroding. Hence, the loss of biodiversity worldwide imposes an increasing risk on the agricultural sector. Essentially, the stock of germplasm within the agricultural system is being renewed at a time interval that is probably around 12 years (100/8). Biodiversity has economic value simply because it serves this maintenance function. Without it, there are risks that the system will not be able to renew itself.

There are several ways of estimating the economic value of this germplasm. First, it could be argued that the economic value of wild crop genetic material is given by what the crop breeding companies are willing to pay for it. At a minimum, this must be equal to that portion of their research and development budgets spent on germplasm from the more remote sources. Second, an effort could be made to estimate the crop output that would be lost if the genetic material was not available. This is an approach based on damages. Third, an attempt could be made to estimate the contribution of the genetic material to crop productivity—a benefits approach. This approach might proceed by asking what the cost would be of replacing or substituting for wild genetic material should it disappear—a 'replacement cost' approach.

As domesticated crops become vulnerable to pests and genetic erosion, so new genetic information is required. The stock of that information provides the insurance against the failure of existing crop genetic stock. There are two sources of vulnerability in the current crop genetic stock: (A) it is based on very few plant families, and (B) there is a high rate of loss of wild genetic stock, mainly because of forest conversion. Hence, there is a 'red queen race,' whereby wild relatives occupy less and less land, and the demand for the genetic information they contain grows rapidly. That demand is increasingly being met from other sources, but wild sources remain important. The role of forests in providing that information should not be exaggerated, however. As far as plant-based foods are concerned, existing widely used crops tend not to emanate from tropical forests but from warm temperate regions and tropical montane areas. The existing 'Vavilov' centers of crop genetic diversity are mainly in areas with low forest diversity. While this suggests that forests could have only a limited role to play as the source of information and diversity for food crops, it should be borne in mind that existing food crops emanate from areas where humans happened to live. It does not follow that forests are irrelevant to future crop production. It seems probable that their value lies more at the regional than at the global level (Reid & Miller 1987).

The informational value of forest diversity for pharmaceutical use is better studied but is also debated. One view argues that the implicit economic value is huge, and the second suggests that it is very modest, at least when converted to economic values per unit of land area. Much of this debate surrounds the 'global' value of medicinal plant material. There is far less dispute about the localized values of traditional medicines, and these are substantial within the context of a local economy (see under NTFPs). These studies are concerned with the values of marginal species, i.e., an extra quantity of species. The total value of biodiversity is clearly unbounded: without biodiversity there would be no human life, and hence, no economic value. This underlines the meaningless nature of some 'economic' approaches to measuring ecosystem value (e.g., Costanza *et al.* 1997). It makes no economic sense to ask for the economic value of 'everything.' In the pharmaceutical context, the relevant economic value is the contribution that one more species makes to the development of new pharmaceutical products, and, by inference, the value of one extra hectare of forested land is the value attached to the species in that area. Table 2 summarizes the values obtained in recent studies for a given hectare of forest in different forest 'hot spot' regions.

Table 2 suggests that pharmaceutical genetic material could be worth several hundreds of dollars per hectare in most hotspot areas and, perhaps, up to several thousands of dollars for selected areas. For the major part of the worlds' forests, however, values will be extremely small or close to zero. Nonetheless, this debate is not closed and more recent attempts to model the value of genetic resources in the context of endogenous economic growth point to potentially high economic values (Göschl & Swanson 1999).

TOURISM AND RECREATION VALUES

Ecotourism is a growing activity and constitutes a potentially valuable nonextractive use of tropical forests. Caveats to this statement are: (A) that it is the net gains to the forest dwellers and/or forest users that matter; (B) tourism expenditures often result in profits for tour organizers who do not reside in or near the forest area and may even be non-nationals; (C) the tourism itself must be 'sustainable,' honoring the ecological carrying capacity of the area for tourists. In principle, tourism values are relevant for any area that is accessible by road or river. Table 4 lists some estimates of tourism values for tropically forested areas. Some ecotourist sites attract enormous numbers of visitors, and consequently, have very high per hectare values. Values clearly vary with location and the nature of the attractions, and none of the studies estimates the extent to which expenditures remain in the region of the forest.

TABLE 2

Estimates of the pharmaceutical value of 'hot spot' land areas ($ per hectare)

Area	Simpson *et al.* (1996) WTP of pharmaceutical companies	Simpson & Craft (1996) 'Social value' of genetic material per ha	Rausser & Small (1998) WTP of pharmaceutical companies
Western Ecuador	20.6	2,888	9,177
Southwestern Sri Lanka	16.8	2,357	7,463
New Caledonia	12.4	1,739	5,473
Madagascar	6.9	961	2,961
Western Ghats of India	4.8	668	2,026
Philippines	4.7	652	1,973
Atlantic Coast Brazil	4.4	619	1,867
Uplands of western Amazonia	2.6	363	1,043
Tanzania	2.1	290	811
Cape Floristic Province, S. Africa	1.7	233	632
Peninsular Malaysia	1.5	206	539
Southwestern Australia	1.2	171	435
Ivory Coast	1.1	160	394
Northern Borneo	1.0	138	332
Eastern Himalayas	1.0	137	332
Colombian Choco	0.8	106	231
Central Chile	0.7	104	231
California Floristic Province	0.2	29	0

WTP = Willingness to pay.

A substantial number of studies exist for the tourism and recreational value of temperate forests (for details see Pearce & Pearce 2001). Indicative values for European and North American forests suggest per person willingness to pay of around $1–3 per visit. The resulting aggregate values for forests could therefore be substantial. Elsasser (1999) suggests that forest recreation in Germany is worth some $2.2 billion per annum for day users alone and a further $0.2 billion for holiday makers.

AMENITY VALUES

There is some evidence that those living near to forests secure a benefit in terms of amenity. The only available studies relate to temperate forests. Estimates are based on the 'hedonic property price model,' whereby house prices reflect the value of the amenity (for details see Pearce & Pearce 2001).

INDIRECT USE VALUES

WATERSHED PROTECTION

Watershed protection functions include: soil conservation—and hence control of siltation and sedimentation; water flow regulation—including flood and storm protection; water supply; water quality regulation—including nutrient outflow. The effects of forest cover removal can be dramatic if nonsustainable timber extraction occurs, but care needs to be taken not to exaggerate the effects of logging and shifting agriculture (Hamilton & King 1983). Table 3 assembles the available evidence.

Watershed protection values appear to be small when expressed per hectare, but it is important to bear in mind that watershed areas may be large, so that a small unit value is being aggregated across a large area. Secondly, such protective functions have a 'public good' characteristic since the benefits accruing to any one house-

TABLE 3

Economic values of forest watershed protection/water supply functions

Study: tropical	Type of watershed protection function	Results
Ammour *et al.* 2000 Guatemala forest	Prevention of soil erosion, universal soil loss equation Valued at cost of soil replacement and at costs of preventing soil loss[1]	Negligible
	Prevention of nutrient loss	
	Nutrients in aerial biomass Valued at fertilizer prices[1]	\$12/ha/annum out of \$30/ha/annum for all NTFPs and environmental services
Kumari 1996 Malaysian forest	Protection of irrigation water, valued at productivity of water in crops[2]	\$15/ha
	Protection of domestic water supplies, valued at treatment cost for improved quality[2]	\$0/ha
Ruitenbeck 1992 Korup, Cameroun	Flood protection only	\$3/ha
Yaron 2001 Mount Cameroun, Cameroun	Flood protection, valued at value of avoidable crop and tree losses	\$0–24/ha
Pattanayak & Kramer 2001 Eastern Indonesia	Drought mitigation from forest protection and regrowth, valued at gain in profits to rice and coffee production	\$3–35 *per household*[3] (compares to \$5–13 per household costs of 're-greening)' = \$0.36 per mm baseflow = 1–10% of annual agricultural profit
Bann 1998 Turkey	Soil erosion valued by replacement cost of nutrients, flood damage	\$46/ha
Adger *et al.* 1995 Mexico	Sedimentation effects on infrastructure	\$ negligible
Shahwahid *et al.* 1997 Malaysia	Impacts of RIL compared with total protection of forests on hydroelectricity	\$4/ha
Hodgson & Dixon 1988 Philippines	Fisheries protection from avoided logging	\$268/ha
Bann 1999 Johor, Malaysia	Shoreline protection by mangrove forest	
	Fisheries protection by mangrove forest	\$845/ha
		\$526/ha
Anderson 1987 Northern Nigeria	Shelterbelts for crop protection	Rate of return increases from 5% (wood benefits only) to 13–17%
	Farm forestry	Rate of return increases from 7% to 14–22%
Study: temperate		
Clinch 1999	Irish temperate forests, water supply	*Minus* \$20/ha

[1]In both cases, the values are replacement costs. This is not strictly a correct valuation procedure, see text.
[2]Valued as the difference between currently unsustainable logging and sustainably managed logging, central case.
[3]Unfortunately, the forest area is not stated.
RIL = reduced impact logging

holder or farmer also accrue to all others in the protected area. Third, the few studies available tend to focus on single attributes of the protective function—nutrient loss, flood prevention, etc.—rather than the totality of protection value. Fourth, the Hodgson and Dixon study (1988) for the Philippines suggests that fisheries protection values could be substantial in locations where there is a major inshore fisheries industry. Comprehensive estimates have still to be researched.

CARBON STORAGE AND SEQUESTRATION

A substantial literature exists on the economic value of global warming damage and the translation of these estimates into the economic value of a marginal tonne of carbon (tC). Tol *et al.* (2000) review the studies and suggest that it is difficult to produce estimates of marginal damage above $50 per tC. Taking $34–50 per tC as the range produces very high estimates for the value of forests as carbon stores. In practical terms, however, a better guide to the value of carbon is what it is likely to be traded at in a 'carbon market.' Zhang (2000) suggests that, if there are no limitations placed on worldwide carbon trading, carbon credits will exchange at just under $10 per tC. Taking the $10 per tC as a very conservative estimate, Table 4 shows the monetary value of carbon in tropical forest land uses.

Table 4 reveals the large values obtained for tropical forests when applying carbon-trading prices. Values of $2000 per hectare can be reached for closed primary and secondary forests. These values relate to forests that are (A) under threat of conversion and (B) capable of being the subject of deforestation avoidance agreements.

OPTION AND EXISTENCE VALUES

An option value exists if someone is willing to pay for conservation of an asset they currently do not use but may use in the future. An existence value refers to a willingness to pay for conservation unrelated to current use or any intended use. The relevance of these values is that they may be 'capturable' through mechanisms such as debt-for-nature swaps, official aid, donations to conservation agencies, and pricing mechanisms. Table 5 shows the results of those studies that have attempted to elicit option and existence values.

As with other environmental goods and services, the general conclusions are: (A) that existence values can be substantial in contexts where the forests in question are themselves unique in some sense or contain some form of highly prized biodiversity—the very high values for spotted owl habitats illustrate this; and (B) that, aggregated across OECD households and across forests generally, existence values are modest when expressed per hectare of forest.

SUMMARY OF ECONOMIC VALUES

Table 6 summarizes the previous economic values. It is important to understand the limitations of the summarized estimates. Values will vary by location so that summary values can do no more than act as approximate indicators of the kinds of values that could be relevant.

Nonetheless, the table suggests that the dominant values are carbon storage and timber. Second, these values are not additive since carbon is lost through logging. Third, conventional (unsustainable) logging is more profitable than sustainable timber management. Fourth, other values do not compete with carbon and timber unless the forests have some unique features or are subject to potentially heavy demand due to proximity to towns. Unique forests (either unique in themselves or as

TABLE 4

Changes in carbon with land use conversion: tropical countries tons of carbon/ha

		Shifting agriculture	Permanent agriculture	Pasture
	Original carbon value $/ha	790	630	630
Closed primary forest	2830	−2040	−2200	−2200
Closed secondary forest	1940	−1060	−1520	−1220
Open forest	1150	−360	−520	−520

habitat for unique species) have high economic values, very much as one would expect. Near-town forests have high values because of recreational demand, familiarity of the forest to people, and the use of NTFPs and fuelwood. Uniqueness tends to be associated with high nonuse value. Fifth, nonuse values for 'general' forests are very modest.

VALUING FOREST CONVERSION

The crude benchmark rule for conservation is that the economic value of conservation must exceed the economic value of conversion. Surprisingly, little is known about conversion values. However, some provisional conclusions can be reached. Despite the early literature suggesting

TABLE 5

Option and existence values for forests

Nature of the good	Study	Result
Protection of 5% more of the worlds' tropical rain forests. Assumes 5% already protected, so scenario is 10% protection. Values reflect existence and bequest.	Kramer & Mercer 1997 Contingent valuation	U.S. residents willing to pay 'one-off' payment of \$21–31 per household. Across 91 million households, suggests \$2.6–2.9 billion. At 5% interest rate, suggests a fund producing \$130–140 million per annum. Divided by 5% of the area of tropical rainforest (720 million ha), this implies about \$4/ha/annum.
Sinharaja forest reserve, Sri Lanka WTP of Sri Lankans only	Gunawardena *et al.* 1999 Contingent valuation	3 groups: peripheral villagers, rural, urban. Use values = 0.5% of income for village, 0.2% for rural, and 0.3% for urban. Bequest values = 0.4, 0.1, 0.2%, respectively. Existence values = 0.2, 0.3, 0.2%. Aggregation is not attempted. Across all rural residents implies \$30 million existence + bequest values, and across all urban would imply \$17 million, i.e., \$447 million in all[1]
Wilderness in Colorado Existence value	Walsh *et al.* 1984	\$12–45/ha, lowest being for the last increments, highest for the first
Forest quality in Colorado (avoided infestation)	Walsh *et al.* 1984	Option value: \$16 per household Existence + bequest value: \$38 per household
Forest quality in South Appalachians (avoid infestation and air pollution)	Haefele *et al.* 1992	Existence + bequest values \$82 per household
Habitat of the Mexican spotted owl	Loomis & Ekstrand 1998	\$102 per U.S. household per annum implies \$4400/ha.
California and Oregon forests, avoided fire risk	Loomis & González-Cabán	\$56 per household in California and New England. Implies \$1.9–9.9 million/ha for all U.S. residents, or \$0.9–4.6 million for respondents only
Implied 'world' willingness to pay for limited forest areas covered by debt-for-nature swaps	Pearce 1996 Implied willingness to pay	\$5/ha
Implies 'world' willingness to pay via Global Environment Facility	Pearce 1996 Implied willingness to pay	\$2/ha
Debt for nature swaps and grant aid to Mexico forest conservation	Adger *et al.* 1995	\$12/ha
Preservation of forest, southeast Australia	Lockwood *et al.* 1993	\$240 per household per annum

[1]It is extremely unlikely that existence values would be common to everyone regardless of distance from the site. The totals here are therefore upper bounds.
WTP = Willingness to pay.

TABLE 6

Summary economic values ($/ha per annum unless otherwise stated)

Forest good or service	Tropical forests	Temperate forests
Timber		
conventional logging	200–4400 (NPV)[1]	
sustainable	300–2660 (NPV)[1]	−4000 to +700 (NPV)[3]
conventional logging	20–440[2]	
sustainable	30–266[2]	
Fuelwood	40	—
NTFPs	0–100	small
Genetic information	0–3000	—
Recreation	2–470 (general)	80
	750 (forests near towns)	
	1000 (unique forests)	
Watershed benefits	15–850	−10 to +50
Climate benefits	360–2200 (GPV)[4]	90–400 (afforestation)
Biodiversity (other than genetics)	?	?
Amenity	—	small
Nonuse values		
option values	n.a.	70?
existence values	2–12	12–45
	4400 (unique areas)	

[1]See Annex 1. 2 of background document.
[2]Annuitized NPV at 10% for illustration.
[3]Pearce (1994).
[4]Assumes compensation for carbon is a one-off payment in the initial period, and hence, is treated as a present value. It is a gross value since no costs are deducted.
NPV = Net present value.

nontimber benefits could greatly outweigh those from slash and burn and/or clear felling, sustainable commercial uses of forest land have considerable difficulty competing with alternative commercial uses, such as conventional logging, agribusiness, and agriculture. Given the difficulties of competing, the importance of 'encashing' the other benefits of forests is to be emphasized, especially carbon storage and sequestration and, where relevant, tourism, watershed protection, and the sale of genetic material.

DISCOUNT RATES

One of the features underlying the land use comparisons is the role of the discount rate. The higher the rate, the less likely it is that sustainable land uses will be favored. This is because high rates favor the early exploitation of land. Conventional logging will tend to be favored over sustainable timber management in such circumstances, as will slash-and-burn agriculture compared with agroforestry and so on. The issue is, therefore, one of knowing how large discount rates are in such contexts. While there is little research on the subject, what exists suggests that local communities often have high discount rates of well over 10% and up to 30% or 40%, reflecting their urgent need to address subsistence and security needs now rather than in the future (Poulos & Whittington 2000). While this conclusion should not be exaggerated—there are many examples of poor communities investing in conservation practices—the available evidence supports the traditional view that many have high discount rates and that these contribute to 'resource mining.'

CONCLUSIONS

While the empirical information is far from adequate, sufficient is known about the value of forest ecosystems to secure some tentative policy conclusions.

First, what is known points to carbon storage values being extremely important. An important policy conclusion follows. Those who have argued in international climate agreements against including forest carbon in tradable permit and offset schemes are, albeit unwittingly, sounding the death knell of forests by removing a major economic argument for their conservation.

Second, early optimism about the role of forests as 'treasure troves' of genetic material for drugs and crops have not had that optimism underpinned by the economic studies to date. This could change, but a great deal more work is needed.

Third, while valuation studies of watershed benefits have not produced large figures to date, watershed 'bargains' between downstream water users and upstream forest owners are rapidly emerging. That the economic value may be small relative to other values does not necessarily mean they cannot form the basis of a conservation bargain since it could be that the values attached to deforestation benefits are themselves small.

Fourth, those who place their faith in sustainable forestry without seeking to 'encash' the nonmarket benefits are likely to be backing the wrong horse. Sustainable forestry pays, but unsustainable forestry pays more.

Fifth, actions to reduce the discount rates of agricultural colonists, e.g., through provision of targeted low-cost credit, would do a lot to encourage sustainable agroforestry practices.

Sixth, potentially large, but unknown, is the value of the forest stock as scientific information, information that may be progressively lost if irreversible deforestation continues apace.

Analysis of forest economic values supports the wider concerns of the ecosystem health literature. Such values point the way to the use of effective economic instruments for forest conservation. Forest loss is associated with damages to human health, climate, watersheds and hence inland and coastal waters via eutrophication and changed water balances, biodiversity and the wellbeing of indigenous peoples (Yazvenko & Rapport 1997; Rapport *et al.* 2001; Rapport *et al.* 1999; Rapport *et al.* 1998a,b; Rapport & Whitford 1999). However, more attention needs to be paid to economic valuation procedures that take explicit account of the irreversibilities of decisions that lead to forest loss (Fisher 2000; Dixit & Pindyck 1994). In this respect, economic valuation of forest ecosystems still has some avenues to develop. In the meantime, what we know points to some powerful arguments for forest conservation.

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