

**TOWARDS ESTIMATING
TOTAL ECONOMIC VALUE
OF FORESTS IN MEXICO**

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Abstract

Failure to account for the numerous functions and economic uses of forests have led to patterns of global forest use with many detrimental environmental consequences. This study demonstrates the economic techniques for estimating the Total Economic Value (TEV) of forests. For the Mexican forest estate, the results show an annual lower bound value of the services of the total forest area to be in the order of \$4 billion. This aggregate value stems from the non-marketed services provided by non-consumptive use; from future potential uses of the genetic resources and from pure existence values; and the largest proportion of economic value coming from the functional values of hydrological and carbon cycling. However, only a proportion of this value can feasibly be 'captured' within Mexico: much of the benefit of Mexico's forests falls outside the country's borders, and is therefore not considered by forest users or national policy makers.

1.Introduction

Forest resources are recognized to have a number of values, including intrinsic, economic, cultural and aesthetic values. Forests have economic value in so far as they are scarce and capable of generating human welfare. Policy decisions are most frequently determined on economic criteria. Yet, it is widely acknowledged that market transactions provide an incomplete picture of total economic value. Those forest benefits which are not normally exchanged in markets are generally ignored in decision-making. Undervaluation of these welfare enhancing services introduces inherent distortions to efficient resource allocation.

In order to improve the efficiency of resource allocation two steps are necessary:

- a)the estimation of the appropriate (shadow) prices for non-marketed or partially marketed forest functions. This is non-market valuation; and
- b)the design of appropriate mechanisms to capture the estimated economic values. This is benefit capture.

Consideration of non-market valuation illuminates the scale of economic distortions due to undervaluation and is a necessary condition for efficient policy making. Social cost-benefit analysis is however, often concerned with equity issues and how benefits accrue to different sectors of society. Indeed, valuation by itself is of little interest to a country owning environmental assets unless they can be turned into revenue flows. "Cashable" benefits for asset owners and users provide the biggest incentive to change their behaviour.

This paper offers estimates of the main components of non timber values for the Mexican forestry sector. We indicate how these benefits accrue spatially (locally, nationally and globally) and provide recommendations on how global values can be internalised within the borders of Mexico.

2. Total Economic Value

The concept of total economic value can be illustrated by comparing two scenarios. In the first, forests are conserved at the present level, and provide a stream of goods and services including timber and non timber products, recreation, climate regulation, carbon sequestration, existence value and so forth. In an extreme alternative scenario, forests and the above benefit streams are absent. The Total Economic Value can then be defined as the amount of resources, expressed

in common units of money, that society would be willing to sacrifice to avoid the move from situation 1 to situation 2, or, that society would be willing to accept as compensation if such a move were to take place.

Total economic value is given by the sum of a number of components (see Pearce, 1993; Randall and Stoll, 1983):

Total Economic Value (TEV) = Direct-use value + Indirect-use value + Option value + Existence value

Direct use values include revenues from timber and values of non-timber forest products. While timber values are not the main focus of interest of this paper, the sector is considered to have considerable commercial potential given appropriate management regimes.

Indirect-use values or "functional" values relate to the ecological functions performed by forests, such as global biogeochemical cycling, the protection of soils, and the regulation of watersheds.

Option value or quasi-option value (Arrow and Fisher, 1974; Henry, 1974) is the expected value of the information on the benefits of an asset, conditional on its preservation enabling an increase in the stock of knowledge relevant to the utilisation of the asset. A frequently evoked example of quasi-option value is associated with genetic resources; for example, future pharmaceuticals developed from plant materials.

Existence value relates to the value of environmental assets irrespective of current or optional uses. Empirical measures of existence values based on donations to conservation organizations, or on the contingent valuation method suggest these can be a significant element in total economic value, especially in contexts where the asset has unique characteristics or cultural significance.

Although intuitively appealing, applications of total economic value to particular environmental resources are few because of the problems of non-additivity of the elements and of quantification of the components. In the forest context, studies of

the individual components of value have been undertaken: estimates of the economic consumer surplus associated with eco-tourism in tropical forests (Tobias and Mendelsohn, 1991, Maille and Mendelsohn, 1993); non-timber forest products (Peters et al., 1989); carbon sequestration functions (Brown and Pearce, 1994); and recreation, landscape and aesthetic values (Hanley and Ruffell, 1993). The study presented here attempts to take these studies further by incorporating all the components of value, calibrated for the Mexico forest types, and is to our knowledge the first attempt at providing such an estimate.

The remainder of this paper concentrates on deriving values for tourism; non-timber forest products; the value of carbon storage; water quality; option value associated with the pharmaceutical uses of genetic material; and existence value. Since an exhaustive coverage of all forest types is beyond the scope of investigation, an implicit assumption is that benefits estimated for one forest site are able to be transferred or extrapolated across the Mexican forest area. Thus damage estimates from soil erosion at one site may be extrapolated to similar sites where site specific data is lacking. Although the legitimacy of benefit transfer procedures are still the subject of academic debate (Brookshire and Neill, 1992, Brookshire, 1992, Krupnick, 1993 for example) we nevertheless make use of them here, as the aim is to present broad orders of magnitude to be used as input to policy making.

3. The Forest Sector in Mexico

Mexico possesses more than 50 million ha of forests, covering a quarter of the total 195 million ha of the national territory. Of total forest area, half is mixed broadleaved tropical forest, and half temperate forest. About 34 million ha are regarded as potential permanent productive forests (Synott, 1993). Despite the extent of commercially valuable forest resources, the sector's contribution to Mexican Gross Domestic Product has only ranged between 1.8 percent and 2 percent in the last decade (Synott, 1993). Domestic production of wood products has been increasingly unable to meet demand, so that Mexico is currently a net importer of all industrial forest product categories, with the exception of wood based panels (Barbier et al., 1993). Although there is no agreement as to the exact magnitude and causes of forest loss, the rate of loss is thought to have increased in recent years, with estimates ranging between 400,000 ha⁻¹ yr⁻¹ and 1.5 million ha⁻¹ yr⁻¹ for the mid 1980s (Barbier et al., 1993).

Approximately one quarter of Mexico's population (of 84.5 million people in 1990) live in forest areas, often subsisting in extreme poverty. Several states with more than 50 percent forest cover (Chiapas, Oaxaca, Guerrero, Yucatan) have 40 percent of their population below the poverty line of \$ 350 per year. The most common form of land tenancy in forest areas is communal, either in *ejidos* accounting for 70 percent of the total forest area, or indigenous communities which account for 5 percent of forest area¹, the remainder being small holder private property.

Significant changes in ownership and control are likely over the next few years. The recently approved North American Free Trade Agreement (NAFTA) will put increasing pressure on traditionally protected and less competitive sectors of the Mexican economy. Reforms of ownership of land precipitated by NAFTA have the objective of allowing the allocation of land among competing uses to become more responsive to international market forces. In the absence of mitigation policies, this is likely to set in motion a process of major structural change in the traditional agriculture and communal forest management, possibly with high social costs.

The process of reform will be facilitated by recent legislative changes, including the reform of Article 27 of the constitution and new agrarian and forestry laws. These changes redefine ownership rights of *ejidos* and communities, allow the disposal of private property and enable outside investors to enter into joint venture with communities. The ultimate outcome of this transformation is still uncertain. Consideration of the full range of forests' values should therefore be an important input in the forthcoming debate on the further evolution of the legislative, institutional and policy framework.

4. Direct Use values

4.1 Tourism and recreation

¹ The Ejido system is a product of post-revolutionary land reforms. Land under the law of ejido tenure was, until recently, a non-negotiable resource. Ejidatarios were granted a plot which was neither sold, transferred or mortgaged, and subject to confiscation if left for more than two years.

Conventional (hotel-beach based) tourism is an important, well-established economic activity in Mexico. In the period 1990 - 1992 total foreign tourism visits averaged 6.4 million per year, with average annual expenditure of US\$ 3.68 billion (SECTUR, 1993). Average growth of 4.8 percent per year over the period 1970-1992 places the sector in the top three foreign currency earners, contributing 1.5 percent to GNP (average 1987-89) and employing 7.3 percent of the country's active population (World Resources Institute, 1992; Boo, 1993; SECTUR, 1993).

Despite the sector's importance, quantitative information is quite limited in detail and disaggregation. Official statistics do not divide visitation or expenditure figures by type of recreational experience, so that there are no specific data on nature-related tourism as such. Furthermore, data on tourism is only systematically collected in the major tourist areas or resorts and rarely at the state level.

Ecotourism and Forest Visitation Rates

Tourism to nature resorts in Mexico can be categorized in two ways: i) multipurpose tourism, which comprises, as part of a larger trip, visits to national parks or other protected areas, lasting one or two days; ii) specialized ecotourism, organized in tours of longer length (between one week and 10-12 days). The two categories can be characterized by opposite patterns of quantity and price. A large volume of short term visitors to national parks pay significantly less than the fewer numbers of ecotourists. This difference can partly be explained by the relative incomes of the two groups. Participation by Mexican nationals tends to be higher in multi-purpose trips relative to foreign visitors.

For a group of six forest resorts (El Triunfo, Sian Ka'an, Izta-Popo, Arrareko, Mariposa Monarca and Barranca del Cobre), it was possible to gather data on area size, annual average numbers of visitors, price paid or estimated willingness to pay for the recreational experience, revenues per year, revenues per hectare per annum. For those areas, **Error! Bookmark not defined.** plots the number of visits against estimated willingness to pay or actual price paid, and illustrates the distinction between "ecotourists" and multi-purpose tourists explained above.

For many protected forest areas in Mexico the distinction between ecotourist and multipurpose visits is often unclear. The distinction can be made according to:

- a) proximity to established resorts or the existence of established infrastructure and communications;
- b) the stated rationale for visits ascertained through written records or established by sample survey.

Thus for example, remote sites such as El Triunfo (Chiapas) would be placed in the eco-tourist category, similarly Sian Ka'an (Quintana Roo) would also be an ecotourist destination because of the nature tourist elements in tours to the Biosphere Reserve.

Since these data refer to a limited number of areas, some inference is required to provide a national picture. In the case of ecotourism, we use an estimate of 20,000 yearly visits, an average stay of 10 days, and a price of \$70 per day. From this, we obtain revenues of \$14m per year². Compared with total expenditure of foreign visitors for the last three years, US\$ 3.6 billion, this amounts to a modest 0.4 percent of the total. It should be noted that some part of the total will include forest-based activities.

In the case of multipurpose tourism, it is estimated that total number of visits to national parks and biosphere reserves ranges between 5.19 and 6.13 million visitors per year³, with individual consumer surplus of around \$ 3.20, as ascertained by a survey conducted for this study in Barranca del Cobre⁴. This gives

² According to Ceballos Lascurain (1988) a 12 day ornithological tour costs about US\$700 per person (not including airfare), i.e. US\$58 per day; Vásquez Sánchez et al. (1992) report a cost of US\$1000 for a 10-day ecological tour of the Selva Lacandona, Chiapas, i.e. US\$100 per person per day. US\$70 per person per day is considered an intermediate value. Regarding number of visits, Ceballos Lascurain suggests about 20,000 people per year participating in ecotourism tours, although this figure relates not only to forest-based activities. The number is likely to be growing in parallel to global rate of 30% per year (Whelan, 1991). In the absence of any better information, a figure of 20,000 per year is used in the present analysis.

³ The only available data from the Ministry for Social Development (Secretaria de Desarrollo Social, SEDESOL) refer to estimated visits per year in each of 18 protected areas in SINAP, the national system of protected areas. By calculating the simple and area-size weighted average of this data and multiplying the result by the total of National Parks and Biosphere Reserves, the range of yearly visitors to protected areas is 5.10 - 6.13 million people.

⁴ The Barranca del Cobre is a pine-oak forested area of 450,000 ha in the sierra Madre mountain region in the state of Chihuahua. A tourism survey was carried out by the authors in May 1993 in order to assess present and potential economic benefits from recreation. A yearly

an overall consumer surplus ranging between US\$ 16.6 and 19.6 million. Summing the *potential* priced benefits of ecotourism (\$ 14m per year) and the unpriced benefits of multipurpose tourism, from the above travel cost estimate (\$16.6 - \$19.6 m per year), produces a total benefit range of \$30.6 - \$33.6 m per year.

average consumer surplus was estimated to be US\$3.27, and average overall willingness to pay for conservation to be US\$8.20.

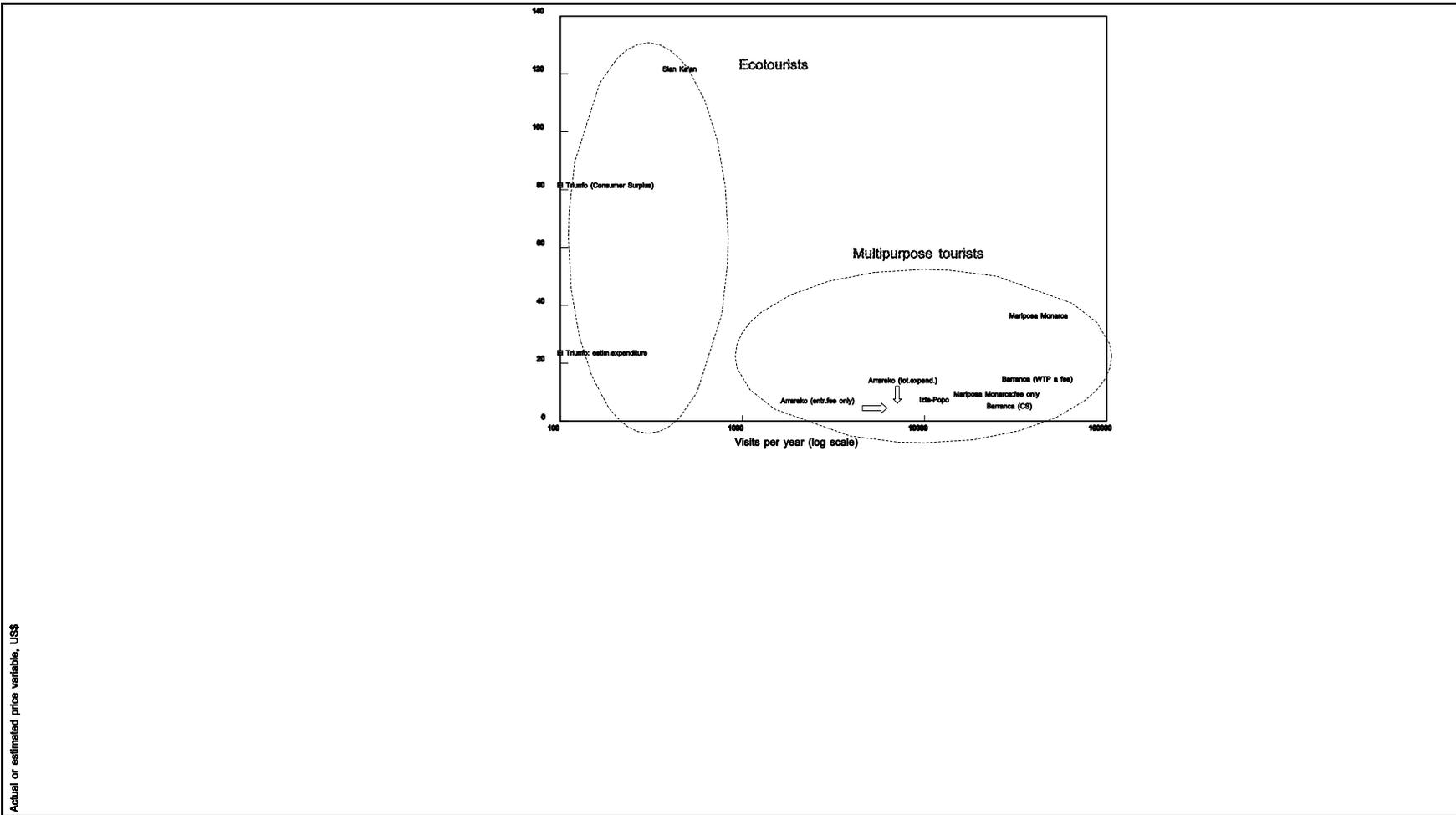


Figure 1 Nature and multipurpose tourism in a group of six areas

4.2 Use value of non-timber forest products

Ethnobotanical studies indicate that over 2000 plant species are utilised from Mexico's forests. These range from products such as resins, turpentine and pitch from Pine forests, and chicle from the chicle forests in the Yucatan, which are internationally traded, to a multiplicity of medicinal plants and wildfoods utilised at a subsistence level.

The task of estimating the use values of these resources is a complex one. Each species has a range of products and different uses, most of which do not have a market price, being used as substitutes for other products, for example. The most in-depth economic analysis of use values of these products in Mexico is Alcorn's work in the southeastern part of San Luis Potosi (Alcorn, 1984, 1989a, 1989b). This examines the management and utilisation of areas of forest groves, known as *te'lom*, in cloud forest and tropical rainforest ecosystems, by indigenous Huastec people. Alcorn estimates the net return to *te'lom* management as being in the region of US\$ 1540 ha⁻¹ year⁻¹ including revenue from coffee, and US\$ 330 ha⁻¹ year⁻¹ excluding coffee (1989 prices). This value has been calculated using shadow prices to assign values to products consumed by the household or used on the farm. This estimate provides an indicative figure of the use value of cloud forest and tropical rainforest environments within a traditional, yet fairly intensive management regime.

Table 1 gives estimates of the use value of selected non-timber forest products (NTFPs) in Mexico. It shows the figures calculated for the Huastec *te'lom*, some of the component values within that use value, and selected figures from other forest areas for comparison. Some of these figures give indications only of likely magnitudes, as the estimates are highly site specific. Bases for comparability between different forest types and different figures are limited. The values are not necessarily additive. However the figures accord well with the few other such studies which exist to date, such as those by Peters et al (1989). in Amazonia, and Balick and Mendelsohn (1992) in Belize. The additive value of the various NTFPs extracted from certain forests may exceed the value of commercial timber.

Table 1: Use Values of selected NTFPs from Mexico's Forests

Product	Region/area	use value Sh ⁻¹ yr ⁻¹	notes
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(US\$ 1989)			
Te'lom grove + coffee	San Luis Potosi	1537	Net of costs
Te'lom grove - coffee	San Luis Potosi	330	Net of costs
Chicle	chicle forests Yucatan	4.9	Average for 3 ejidos in Quintana Roo (net of costs)
Allspice	Rain forest, Peten, Guatemala	3.3	Estimate for Peten
Building materials	San Luis Potosi	20.3	Net of costs
Medicines ¹	San Luis Potosi	51.7	Cost of avoided doctor visits
Fuelwood	San Luis Potosi	14.5	Shadow price of labour method
Fruits	San Luis Potosi	401	Net of costs, half the product marketed
Mushrooms	Pine forest	3.1 - 281	Costs not subtracted, 1 spp only
	Fir-Pine forest	20.1 - 97	Costs not subtracted, 1 spp only
Game meat	Quintana Roo	9.0	One ejido
Birds	all Mexico	0.01	Indicative only
Game trophies	Chiapas	0.02	Indicative only

¹ Falls within the range of \$19-61 calculated by Balick and Mendelsohn (1992) in Belize.
Sources: Bye et al. (1993)

The use value of NTFPs is likely to be relatively high compared to other values, and possibly very high in certain regions, given particular modes of management. However many of the figures presented are indicative of particular sites. There are problems in extrapolating from small case study or sample areas to regional or national scale since expanded supply will lower unit values, and data on the amount of time spent collecting and processing NTFPs and other costs, especially opportunity costs, is required. The use of NTFPs may make substantial contribution to livelihood strategies of rural people in certain area, particularly providing building materials, fodder and wildfoods. This contributions is likely to

be especially important for poorer sections of the community, who might be able to benefit from policies designed to maximise the values of NTFPs.

5.Functional Values

Two functional values of forests are estimated here: the value of forests in their role in the global carbon cycle and the value of the functions in the hydrological cycle. The appropriate economic technique on estimating TEV is that of the loss in economic activity avoided by conserving the resource. In the case of the global carbon cycle it is the avoidance or postponement of the impact of future climate change through the build up of atmospheric greenhouse gases; and for watershed protection it is the offsite and onsite costs of soil erosion which inevitably occurs when forests are lost in critical upland areas.

5.1 Carbon storage

The carbon sequestration benefits of forest conservation and of plantation forestry is estimated in a two stage process. First, the carbon sequestration and storage is estimated through physical models of forest type and land use change. The carbon sequestration depends on the species mix; the organic matter content of the species; the age distribution of the stand, and soil and climate factors. Below ground biomass also is a critical part of the net flux. The second stage is to place a monetary value on this forest function in terms of global warming damage avoided.

To estimate the carbon storage in forests, and hence the fluxes involved in the loss of forests, several methods are available, such as extrapolation from experimental plots and modelling from inventory data. Forest inventory data can be used to estimate the above and below ground biomass of regional areas (see Brown and Lugo, 1992; Fearnside et al., 1993). A difficulty with any accounting approach however, is in the assumption of the simple dynamics of land use change. There tends to be a sequence of conversion activity: although the forest area may be converted to agriculture, this may after a few years be converted into permanent pasture for cattle. Even this use may be transient, if the land cannot sustain ranching and is eventually eroded. It is assumed in estimating carbon fluxes that the next land use continues for an indefinite period. Although this may not reflect the reality of the conversion process, the major carbon fluxes occur at deforestation

and the subsequent changes are therefore assumed to be insignificant (unless reforestation or regeneration occurs) (see Adger and Brown, 1994).

Table 2: Once for all carbon fluxes from changing land uses in Mexico

Forest Type	Converted land use	
	Permanent Pasture (tC ha ⁻¹)	Agriculture (tC ha ⁻¹)
Temperate Coniferous	168.4	167.1
Temperate Deciduous	34.0	31.5
Tropical Evergreen	164.8	163.5
Tropical Deciduous	92.5	91.25

Sources: Own calculations based on Brown (1992), Houghton et al. (1991) and Masera et al (1992).

The conversion process of forests to other activities generally involves a series of intermediate stages as discussed above. The predominant subsequent uses are agricultural - ranching or cropping. The once for all carbon fluxes associated with those land use changes are shown in Table 2. Other reasons for forest loss include road building and erosion, though this is relatively small in areal terms (<10% of the forest area lost). The results in Table 2 show a range from >30 tC ha⁻¹ lost with forest loss to >160 tC ha⁻¹, for the predominant subsequent uses.

The economic value of carbon sequestration

As discussed above, the forests have a role in the global carbon cycle, but net atmospheric accumulation of greenhouse gases due to growing emissions will cause global warming in the future. Global warming and climatic change will have a number of serious impacts on ecosystems, economies and regions, such as accelerated sea level rise; unknown impacts on agriculture due to temperature and precipitation changes; impacts on demand for energy and other economic activities; health related impacts and others (see for example Rosenzweig and Parry, 1994; Haines, 1993; Schneider, 1992). Of greatest concern is the uncertainty surrounding the magnitude and distribution of any changes, and several catastrophic scenarios have been suggested due to changes in prevailing winds and ocean currents. Activities which reduce emissions or enhance sinks of the trace

gases, primarily CO₂, have then a value to society equal to the expected damage avoided.

Several studies now exist attempting to put a money value on global warming damages (Fankhauser, 1994; Nordhaus, 1991, 1992; Cline, 1992). The procedure is generally to relate temperature changes to physical impacts, then apply economic values to these impacts⁵. These studies are associated with various emissions scenarios and damage and abatement functions but rely critically on extrapolation from one economy (the US) across all regions of the world. The earlier studies by Nordhaus and Cline (1991) have been refined by Fankhauser (1994) who sub-divides the climatic change impacts on the world economy by region. Fankhauser's estimates are based on a study which explicitly allows for uncertainty by incorporating random variables, such as the climate sensitivity to the doubling of atmospheric concentrations of CO₂ and the discount rate and damage estimates. The randomisation is generally a closer representation of current scientific understanding of the greenhouse effect than the use of best guess values. We take Fankhauser's central estimate for current emissions of \$20 per tC and apply them to the once for all carbon flux changes to give a capital value to the world of the global warming damage avoided in maintaining the four generalised Mexican categories of forest. The results are then shown in Table 3.

⁵ These values may be based on market prices, or estimates of non-market values such as the "statistical value of life" for mortality and morbidity effects.

Table 3: Value of Carbon Sequestration from Forest Conservation (Present Value \$ per ha)

Forest Type	Converted land use	
	Permanent Pasture (\$ ha ⁻¹)	Agriculture (\$ ha ⁻¹)
Temperate Coniferous	3436	3410
Temperate Deciduous	693	643
Tropical Evergreen	3633	3337
Tropical Deciduous	1887	1863

Notes: Based on social value of \$20 per tC and once for all fluxes as estimated above.

The results show that the value of avoiding the carbon fluxes associated with changing land use range from \$650 to \$3400 (equivalent to \$20 to \$100 per ha per year), depending on the forest type and the subsequent land use. This is a social value in that this is the benefit of avoiding global warming impacts in the global sense. It is not therefore either the benefit captured by Mexico for carbon sequestration, nor the financial or opportunity cost of forest conservation from the perspective of the forest owners. We judge these estimates to be conservative for a number of reasons:

- a) With a time related profile of carbon flux changes, the value of fluxes occurring in future time periods increases in the models of global warming damage.
- b) The carbon fluxes estimates are mid-range estimates of the differences between biomass and soil accumulation by different forest types. Other studies have estimated higher carbon fluxes from land use change, though ongoing experimental research will shed light on these results.
- c) Non CO₂ trace gases are emitted in biomass burning, the process by which forest is lost in many cases (see Crutzen and Andreae, 1990; Cofer et al., 1993).

These gases such as CH₄ are more potent greenhouse gases, and add to the climate change impact. Again this and the other economic factors mentioned above give a conservative estimate of the economic cost of global warming damage, and hence of the value of the carbon storage function of Mexico's forests.

5.2 Watershed protection

Deforestation, hydrology and soil erosion

Although the damaging effects of deforestation have been confirmed in experimental trials, site-specific valuation of forest hydrological functions is complex due to the heterogeneity of forest types, geological and climatic factors, and to difficulties in valuing impacts (Bruijneel, 1990). Deforestation exposes forest soils, and erosion effects are worsened by clearance and extraction using logging tracks and new roads. Quantifiable damages includes increased soil erosion entailing on-site and off-site sedimentation costs; accelerated water run-off leading to localised flooding; and reduced hydrological cycling and recharge of groundwater and watercourses.

The costs of mitigation or reparation of damages provides a surrogate measure of the value of these protective forest functions⁶. Data limitations confine estimates for Mexico to those from sedimentation damages on infrastructure: damages from increased flooding and reduced water remain unquantified, giving lower bound estimates of the true value of this forest function.

Sedimentation costs

There is considerable uncertainty in linking regional water quality degradation to deforestation. This uncertainty is primarily due to the non-point nature of the sources of sedimentation. In Mexico the historical and current loss of forest cover in watersheds is undoubtedly a principal factor in accelerating soil loss. Maas et al., (1988) report up to a hundredfold increase in soil loss through forest conversion for experimental trials in Jalisco (0.20 t ha⁻¹ year compared to a highest value of 130 t ha⁻¹ year under maize, see Table 4). Extensive measurement in watersheds across hydrological sub-regions indicates a typical average range of 0.169 to 7.43 t ha⁻¹ year although averaging across catchments disguises extreme

⁶ Strictly reparation costs are a minimum estimate of damage only if it can be assumed that it is worth repairing the damages.

cases of up to 50 t ha⁻¹ year. Quantification of external costs of soil erosion have received far less attention than more easily observed on-farm productivity benefits of erosion control (Schramm, 1982). In Mexico little is known of the relative magnitudes of on site and off site costs although limited U.S. estimates indicate that offsite costs are significant⁷.

For water quality some degree of the benefit of forest cover can be estimated by considering the likely extent of defensive expenditures required nationally for water purification of suspended sediment. Martínez-Menez and Fernández (1984) estimate an average annual sediment production figure of 365 million tonnes, although without specifying where this originates. Of this an estimated 69 percent is carried to the sea and 31 percent is discharged in waterways and other hydrological infrastructure. Assuming that all 113 million tonnes of deposition induces some form of purification and using an average figure calculated for the U.S. for induced treatment costs of \$20 per thousand tonnes of discharge (Holmes, 1988), a rough lower bound cost is estimated as \$2.3 million per year (1989 prices) for all sedimentation in Mexico.

Existing research suggests that likely savings to the water treatment industry from reduced erosion are a relatively minor benefit (Holmes, 1988). This is confirmed by the estimates derived here. It is noted however, that more vulnerable watersheds with high sediment loading rates may have significant problems. Specific examples of the benefit of forest cover due to avoided replacement purification costs may be in the range of \$50 - \$150 per hectare. Since these represent one-off or periodic costs avoided, they do not approximate annual losses. In the absence of more detailed cost information this is assumed as the typical range for vulnerable watersheds.

Infrastructural Damage

Despite the consensus on the severity of infrastructural damage from sedimentation, there is little organized information on which to base damage estimates. Casual evidence from national electricity generators responsible for

⁷ Clark (1985) estimates US\$2.2 billion per year as a cropland share of total offsite soil erosion damage. A more modest figure of US\$353 million per year based only on water treatment costs is suggested by Holmes (1988).

major dam projects in Mexico suggests that sedimentation rates have been (and possibly still are) underestimated leading to curtailed lifespans and misguided investment signals. Such costs are often amplified by the social costs of habitat destruction and community relocation to make way for flood sites (for example, the case for the Aguamilpa hydropower project in Nayarit and Zimapán project in Queretaro and Hidalgo). Nevertheless the existence of comprehensive state erosion figures (SARH, 1987) and information on vulnerable hydrological areas suggests that there is considerable information with which to direct watershed management. Some representative economic studies are required to demonstrate the extent of losses and mobilize resources to tackle the problem⁸.

Watershed regularization

The hydrological and flood regulatory benefits of forest cover are well known although there appears to be little information on Mexican watersheds. Measurable benefits are likely to accrue in three areas: a) mitigation of flood damage; b) groundwater recharge; c) assurance of urban water supplies. Flood damage to crops is a periodic occurrence in several low-lying areas and there is evidence that watershed deforestation has aggravated the volume of run-off (most notably, the watershed of the Rio Paloapan, Veracruz). Estimated damage mitigation benefits are site specific and are difficult to attribute to discrete areas of forest cover. Existing protected area studies in other countries attempt to make broad with/without estimates of likely flood damages and water supply benefits (Gutman, 1992, Ruitenbeek, 1989).

The balance of existing information suggests that the external costs of soil loss and implicitly some proportion of the benefits of forest preservation impact in various ways. Measurement of the economic costs may be by several methods some of which more relevant in the Mexican context. The most significant offsite damages from forest conversion are sedimentation costs and alterations to hydrological balances. Table 4 summarises erosion estimates for different sites in Mexico.

⁸ An exemplary application dealing with these economic costs in the Philippines is Cruz et al. (1988).

Table 4: Selected Erosion Estimates for Mexico

Authors	Measurement
Estrada and Ortíz-Solorio (1982)	Average losses in excess of 50 t ha ⁻¹ year ⁻¹ using FAO methodology; location unclear.
Martínez-Menez and Fernández (1983)	Average losses of only 5 t ha ⁻¹ year ⁻¹ using suspended sediment measurement in main watersheds.
Maas and García-Oliva (1990)	From a review of studies state an average range of 0 - 15 t ha ⁻¹ year ⁻¹ in cultivated areas with modest slopes.
Raa (1983)	Study in mountain area; cuenca alta del rio La Antigua (Veracruz) range 13.5 - 1296 t ha ⁻¹ year ⁻¹
Torres (1987)	Range 30.4 - 151.7 t ha ⁻¹ year ⁻¹ over 4 months; cuenca alta Rio San Marcos (Tamaulipas)
Maas et al. (1988)	Range 30 - 130 t ha ⁻¹ year ⁻¹ , Chamela research station, coastal Jalisco.

Sources: given in table

6. Option Value of Pharmaceutical from Mexico's Forests

A major argument for the preservation of biological diversity, when many species and their properties remain unknown, is the *potential* uses of these resources. This diversity is therefore valued for the options that it represents. Option value can be conceptualised as being similar to an insurance premium, paid to ensure the supply of an asset, the availability of which would otherwise be uncertain (Pearce, 1993). Option value reflects the willingness of a risk-averse society to pay a premium, on top of the use value itself, for guaranteeing access to a resource of uncertain future supply.

An indication of the potential information value of genetic diversity in Mexico is illustrated by the example of *Zea diploperennis*. This wild species of maize (known as a *teosinte*) was discovered in the Mexican state of Jalisco in the 1970s,

and its most valuable characteristics are that it is perennial and shows resistance to certain viruses. Fisher and Hanemann (1985) have estimated that *Zea diploperennis* may have value of \$6.83 billion per year for its use in the creation of perennial maize only. The discovery of the *teosinte* has resulted in the establishment of a 135,000 ha Reserva Biosfera de la Sierra de Manantlan in 1987 (Iltis, 1988), which will enable to protect not only this teosinte, but also the other species of the mountain habitat.

The option value of forests as habitats for species likely to yield pharmacologically active substances is often cited as a reason for promoting forest conservation. Although the medicinal value of plants and their derivatives has been recognised for millennia, the estimation of the importance and economic value of the biodiversity which gives rise to the possibility of more discoveries is a very recent field of interest (for estimates of the number of plant species used as sources of drugs in western medicine see Bell, 1993; Principe, 1991; Farnsworth and Soejarto, 1985).

The option value, or more strictly quasi-option value (Arrow and Fisher, 1974; Henry, 1974), of pharmaceuticals derived from genetic material in Mexico's forests is estimated using a model which takes into account the number of species present in Mexico's forests; the probability of a species yielding a useful product; the royalty rate on sales of such a product which would be payable to Mexico; a coefficient of rent capture; the likely value of an internationally traded pharmaceutical product; and the area of forest.

The model, developed by Pearce and Puroshothaman (1992), estimates option values as a function of the number of species at risk, the number of drugs based on plant species, and the number of hectares likely to support medicinal plants (which they take to be total area of tropical forest). They suggest commercial values in the range from very low to around \$20 per hectare. These values can be construed as lower bound estimates, given that these relate only to species at risk, and the loss of large tracts of tropical forest would place many other plant species at risk.

The methodology used here to estimate the option value of pharmaceuticals from Mexico's forests is adapted from Pearce and Puroshothaman and calibrated for Mexico.

The basic formula, which expresses the value on a per hectare basis is then:

$$V_p(L) = \{ N \cdot p \cdot r \cdot a \cdot V/n \} / H \text{ per annum}$$

Where:

- $V_p(L)$ = The pharmaceutical value of a hectare of forest (US\$/ha)
- N = The number of plant species in forests
- p = The probability of a "hit"
- r = The royalty rate
- a = The appropriation rate, or rent capture
- V/n = The average value of drugs developed (US\$ per year)
- H = The area of forest (ha)

These components and their empirical magnitudes for Mexico are dependent on the diversity of species, including vascular plants and micro-organisms⁹ and animal species (extremely high in a megadiverse country like Mexico (WCMC, 1992; Bye, 1993; Bye et al., 1993; Toledo et al., 1992)); institutional factors affecting the return to Mexico from a discovery with global implications; the area of Mexico's forests; and factors exogenous to Mexico such as the technology employed by drug prospecting companies. Based on the best guess factors for the Mexico case, a range of potential values given in Table 5 can be identified.

Table 5: Option Value of Pharmaceuticals from Mexico's Forests

	Option value moist tropical forests US\$ ha ⁻¹ yr ⁻¹	Option value MTF US\$ million yr ⁻¹	Option value, all forests US\$ million yr ⁻¹
LOW	1	5	26
MEDIUM	6	66	332
HIGH	90	875	4646

Assumptions:

⁹ The biggest group of therapeutic drugs, antibiotics, are derived from *penicillium* molds (Oldfield, 1984).

5000 species is the lower estimate of the number of species in Moist Tropical Forests (MTF) in Mexico, and therefore represents the lowest estimate for all forests.

Forest areas: 9.7 million ha MTF; 51.5 million ha all forests.

Probability of a hit is 0.0005, royalty rate 0.05.

Low estimate:	appropriation rate = 0.1,	drug value = US\$0.39 m/yr
Medium estimate:	appropriation rate = 0.5,	drug value = US\$ 1 bn/yr
High estimate:	appropriation rate = 1,	drug value = US\$ 7 bn/yr.

7.Existence Values

Existence value derives from the knowledge of a resource's continued existence, independent of any use. There are several plausible underlying motivations for existence value which have been widely covered in social science literature (Randall and Stoll, 1983 for example).

From the methodological standpoint, measurement of existence value is perhaps the least tractable and most contentious aspect of natural resource valuation. The available developed country evidence (summarised in Pearce, 1993), suggests that non users have typically indicated values in the range US\$1.2 - 64 per annum per person for wild species, while per annum WTP for scenic and wilderness areas range between US\$9 and \$107. To the extent that the latter estimates could be extended to large groups of the populations involved, the resulting aggregate figures are likely to be quite significant, and increased effort to measure and appropriate existence value seems to be warranted. For the time being existing studies provide indicative values where full-blown studies are not possible at different sites. The wisdom of transferring benefit estimates from other similar sites continues to be the subject of scrutiny in valuation literature (Brookshire and Neill, 1992). An important caveat for this study is that most valuation studies have been carried out in the US or in other developed countries, and may therefore have a limited applicability to Latin American countries like Mexico.

Table 6 presents elements of revealed value for a sample of transactions related to natural area conservation in Mexico. Reported elements include contributions to conservation organizations and programmes, a tourism survey carried out by the

authors, and debt for nature swaps. On the basis of this evidence, indicative per hectare values would appear to be in the range (0.03 - 10.4 US\$ ha⁻¹). Multiplying the upper bound of that range over the extent of Mexico's protected areas (approximately 5.8 million hectares) provides a conservative estimate of US\$ 60.2m. Given the diversity of protected areas it is fair to suggest that only a proportion of this value is attributable to forest areas.

Some comparison with other Latin American country data can be made using estimates of existence value implicit in debt-for-nature (DFN) transactions. As reported by Pearce and Moran (1994), the range of implicit values is from around \$0.01 ha⁻¹ to just over \$4 ha⁻¹. The idea of valuing the biodiversity so conserved through DFNs is that the payment made reflects some kind of willingness to pay on the part of the conservation body purchasing the debt. Different DFNs can be expected to derive different implicit valuations since the nature of the 'good' being bought will vary. For example, the quality of the area protected will vary, and different packages of measures will be involved.

Table 6: Evidence of Existence Value in Mexico

Type of Evidence	Organization Involved	Area Involved	Size (ha)	Amount of Transaction (US\$)	WTP per hectare (US\$)	Comments	Source
Debt for Nature Swap	Conservation International	Selva Lacandona; Montes Azules (Chiapas)	385,000	4,000,000	10.38		Tajbakhsh (1993)
Donations for Nature Conservation Organizations	Amigos de Sian Ka'an (Cancun, Quintana Roo)	Sian Ka'an biosphere reserve (Quintana Roo)	528,147	34,000	0.06 0.05	The first figure is the total amount of donations for 1992; Sian Ka'an report that only 10 percent of donors have actually visited the reserve.	Bezauri (1993)
	Pronatura (Mexico City)		Not Available	\$809,622	NA	The figure refers to total 1992 receipts of Pronatura, including donations and other sources of income	Herman (1993)
On-site evidence, visitors' survey		Barranca del Cobre (Chihuahua)	450,000	100,100	4.4	A survey carried out in Barranca del Cobre suggests a WTP/ person/year related to existence value of US\$ 1.82. Multiplying this by the number of visitor per annum (55,000 in 1992) gives a total of US\$ 100,100; and at a 5 percent discount rate, a present value of US\$ 4.4	Authors' Survey
US Contributions to biodiversity conservation projects in	World Resources Institute, Washington D.C.	Several areas	190,869,000	5,528,809 (1989 US\$)	0.029	Areas involved in the calculation are those contained in a WRI biodiversity projects database.	Abramovitz (1991)

Mexico							
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Sources: as given in table

8. Aggregate Values

Table 7 provides aggregate estimates for the elements of TEV discussed above. In general, conservative estimates have been presented. For example, for option value the upper bound figure is many times greater than the mid range estimate used. Similarly, the true population over which existence value should be estimated is the world, and higher estimates would result. No aggregate estimate has been extrapolated for NTFPs as explained above. In summary the results show that the benefits of non-timber forest products are significant in forest management decisions. Intensive management, for example can produce \$330 ha⁻¹ yr⁻¹ value added. Important forest products include chicle, medicines and mushrooms and building materials. Non-market functional values have the greatest global value, higher than option, existence or indirect use values.

The carbon sequestration function of forests provides large global benefits. A range of capital carbon value from \$650 - \$3400 per ha is estimated (shown as annual value in Table 8 of \$20 - \$100 ha⁻¹ yr⁻¹). This functional value alone is greater than typical land values in tropical forest areas in many parts of the world. Watershed protection is estimated at \$2.3 million per year from sedimentation costs alone. Other functions such as watershed regulation would expand this lower bound figure. Although this is lower than other values, it is a highly localised problem.

The option value of pharmaceuticals is estimated in the range from \$26 - \$4600 million, with a central estimate of \$330 million in Table 7. This value stems from the probability of discovering genetic material in the average hectare of forest which may yield billion dollar benefits. Existence value can be imputed from the willingness to pay for conservation of international agencies, or from direct survey responses. A value of \$60 million is estimated for Mexico. The non-priced benefits of ecotourism and the priced benefits of multipurpose tourism, the total benefits range obtained is \$30.6 - \$33.6 m per year.

The size of these values leads us to conclude that there are considerable returns (both to private decision-makers and to society) if these can be captured. The following section outlines some mechanisms available to maximise and capture some of the component values of TEV.

Table 7: Estimated Values of Elements of TEV of Mexican Forests

	<i>Area (m ha)</i>	Tourism	NTFP's	Carbon	Water- shed Protect- ion	Option Value	Exist- ence value
Tropical Evergreen	9.7		\$330/ ha/yr	\$100/ ha/yr		\$6.4/ ha/yr	
Tropical Deciduous	16.1			\$56/ ha/yr			
Temperate Coniferous	16.9			\$103/ ha/yr			
Temperate Deciduous	8.8		\$330/ ha/yr	£20/ ha/yr			
Total (\$m/yr)	51.5	\$32.1m	n/a	\$3788.3m	\$2.3m	\$331.7m	\$60.2m

Sources and notes:

Forest areas from: Masera et al. (1992). Excludes open forest and scrubland. Option value is a conservative estimate based on the quasi option value of genetic resources in tropical forests. No estimate of aggregate value of NTFPs is available. The \$330 ha⁻¹ yr⁻¹ (1989 prices) in the table represents returns from intensively managed *te'lom* systems only as an indication of the multiple use of forests. Watershed protection (1989 prices) includes water quality only (not infrastructure costs). The carbon figures are annuitised sums (assuming a 3% discount rate) of the capital values of carbon sequestration (\$650 - \$3400), reported in Table 3.

9. Capturing the Values

Non-timber Forest Products

Enhancing the value of NTFPs and increasing the capture of their value could bring significant benefits to poorer sections of rural communities, both in terms of providing subsistence goods, such as building materials, where substitutes might be expensive and produced outside the area, and in terms of direct income generation. Many NTFPs, for example chicle, provide the bulk of cash income for some households. However, producers of such products are vulnerable to shifts in

demand and price fluctuations. However, there are opportunities for 'win-win' policies which provide income generation for local people, and encourage sustainable utilisation of forests, through developing NTFPs. Such strategies are explored for example in volumes edited by Anderson (1990) and Redford and Padoch (1992).

The market potential for many valuable NTFPs is little known. For example, ornamental palms (*xate*), allspice and mushrooms have been identified in previous studies (Reining and Heinzman, 1992; Snook et al., 1989) as marketable species. The development of markets is required, both nationally and internationally which ensure that local gatherers and managers are able to capture more of value of NTFPs, but which recognise that the expansion of these markets increases vulnerability to international price fluctuations.

Carbon Values

Offset deals are one possible mechanism for the appropriation of global carbon values. These agreements involve a commitment of forest users to a forestry management plan which maximises carbon sequestration in exchange for an annual payment which represents a carbon credit for the financier. In the past, success of schemes have crucially depended upon coordination of the individuals involved in forest management. Existing community structures of ejidos, association of ejidos and indigenous communities are institutional structures already in place and which can guarantee the coordination of individual actions necessary for the operation of offset deals (Faeth et al., 1994; Dixon et al., 1993). Indeed there are examples of such schemes proposed in Mexico. The Union de Comunidades y Ejidos Forestales de Oaxaca (UCEFO) propose to promote growth of biomass and of forest area to sequester 2.7 million tC by 2030. The cost of undertaking this management strategy translates to approximately \$3 per tC sequestered (Faeth et al., 1994).

Although these offset deals will become more frequent in the context of the UN Framework Convention on Climate Change (Brown and Adger, 1994), and do provide one source of finance for implementing management plans, their impact of such deals in terms of the large global value of the carbon cycling function of forests is small. This is due to the institutional problems associated with such offset deals and also to the fundamental non-action on the future threat of the impacts of

human-induced climate change as described in the section on valuation of this forest function.

Tourism

Ecotourism in Mexico is currently characterized by low number of visits and high willingness to pay. Operating just on the quantity side, i.e. by encouraging a higher number of visits, could lead to a significant increase in revenue. For instance, just diverting 1 percent of foreign tourists from conventional tourism, with an average of expenditure US\$ 40 per person per day, to ecotourism, with expenditure of US\$ 70 per person per day, would generate an increase in revenues of about US\$ 8.8m per year.

In the case of multipurpose tourism, we observe the opposite pattern: higher visitor numbers but lower price paid per visit. Here a strategy could be followed, which would increase, or in some cases establish, charges associated to the recreational experience. Entrance fees to protected areas should be higher for international visitors. This could be justified on efficiency grounds (higher foreign recreational values) and on equity grounds (per capita income levels of US and European visitors are higher than domestic incomes). By using the lower bound non-Mexican willingness to pay obtained from the mentioned survey in Barranca del Cobre (US\$ 8) as a benchmark for an average entrance fee, and assuming that about 25 percent of visitors to protected areas are foreign, it is estimated that the resulting additional revenues would lie somewhere between US\$ 10.4m and US\$ 12.6m per year.

Option Values

The scope for biodiversity prospecting contracts with conservation of genetic resources have been highlighted by recent developments in other countries (see for example Reid et al., 1993), and given the high option value of Mexico's biodiverse forests, Mexico is well placed to capture this value. It has large amounts of expertise compared with other developing countries, but requires bolstering of research and development facilities, and clarification of property rights. Agreements at the moment would seem likely to be developed through private organisations, perhaps in collaboration with educational and research institutions. If linked in with conservation projects at a local level, then there are opportunities for innovative involvement perhaps of communities or groups of ejidos.

Existence Value

The international community may reveal its willingness to pay for conservation by engaging in some kind of trade of land use rights. Landowners would give up rights on some uses of land (e.g. burning the forest, or developing land beyond a given level of intensity) *in exchange* for a money payment. Land users would retain rights to conservation compatible activities (e.g. sustainable forestry, Non Timber Forest Products gathering). Those carrying out these activities would then have two sources of income: the proceeds of the activity itself, *plus* the fee paid by the conservation agency for giving up the right to other uses.

Several alternative avenues offer potential for viable trades in conservation between Mexico and the international community. Options differ according to the choice of the *intermediary structure* linking the buyer (the international community) and seller (the resource users).

One possibility would be to have federal or local government as intermediary between the international community and resource users, as in the proposed Franchise Agreements scheme¹⁰. An alternative would be to let private entities play the role of intermediary. This appears to be the basis of the program of the newly constituted Foundation for the Conservation of Biotic Resources (FUNDAREB) (Laird, 1993). Although still in the program design stage, FUNDAREB's intention is to pool in a company the financial resources required to initiate a program of land use rights purchase. In a second stage, its share in the company could be partly or totally sold in the market, and should the initial experiences be successful, new acquisitions could be started. To make the program possible, FUNDAREB has proposed the introduction of *conservation easements* or of other forms of property rights attenuation in the Mexican legislation¹¹.

¹⁰ An IFA is a concession, by the state, of exclusive rights on land to a franchisee, with limitation on allowable uses in the interest of a third party; for details, see Swanson (1992), and Cervigni (1993).

¹¹ The use of land easements (US) or covenants (UK) are well established use right attenuation schemes for areas of environmental, cultural or historic interest.

10. Conclusions

Forests are multi-functional ecosystems with numerous uses by humans. Failure to recognise and account for these multiple uses have led to patterns of global forest use with many detrimental environmental consequences. In economic terms, it is the *public good* nature of the environmental services which leads to this detrimental resource use. This paper has demonstrated the economic techniques for valuing these non-marketed services and has applied these techniques to the Mexican forest case. The results show an annual lower bound value of the services of Mexico's forests to be in the order of \$4 billion. These values stem from the non-marketed services provided by non-consumptive use; from future potential uses of the genetic resources and from pure existence values; and the largest proportion of economic value coming from the functional values of hydrological and carbon cycling.

The implications for Mexico's forest policy stem from the observation that a large proportion of these values accrue globally: that global human society benefits as much from the existence of Mexico's forests as Mexicans do. Two conclusions follow from this observation. First, to capture at least part of this global value, international mechanisms would be required. These may be government levies on international tourists to Mexico, or international transfers for carbon offsets or biodiversity conservation. Secondly, a clearer understanding is required of the economic and other 'values' of forests which are inherent in forest users' decisions. This paper has demonstrated that a strong case can be made for forest conservation in the Mexican case, based on local, regional and global values of forests, and that these values should be incorporated into decisions on the future management of this important resource.

References

- Abramovitz, J.N. 1991. *Investing in Biological Diversity: US Research and Conservation Efforts in Developing Countries*, World Resource Institute, Washington DC.
- Adger, W.N. and Brown, K. 1994. *Land Use and the Causes of Global Warming*. John Wiley, Chichester.
- Alcorn, J.B. 1984. *Huastec Mayan Ethnobotany*. University of Texas Press, Austin, Texas.
- Alcorn, J.B. 1989a. An economic analysis of Huastec Mayan forest management. In: *Fragile Lands of Latin America* Browder, J. O. (ed.). Westview Press, Boulder Co. pp 182-206.
- Alcorn, J.B. 1989b. Process as resource: The traditional agricultural ideology of Bora and Huastec resource management and its implications for research. *Advances in Economic Botany* 7, 63-77.
- Anderson, A.B. (ed) 1990. *Alternatives to Deforestation*. Columbia University Press, New York.
- Arrow, K.J., and Fisher, A.C. 1974. Environmental preservation, uncertainty and irreversibility. *Quarterly Journal of Economics* 88, 312-319.
- Balick, M.J. and Mendelsohn, R. 1992. Assessing the economic value of traditional medicines from tropical rainforests. *Conservation Biology* 6, 128-130.
- Barbier, E., Burgess, J., Collins, M., and Clancy, C. 1993. *Mexico Forestry Sector and Conservation Review: Substudy of Economic Issues for Implementation of the New Forestry Policy*, London Environmental Economics Centre report to the World Bank, Washington DC.
- Bell, E.A. 1993. Mankind and plants: The need to conserve biodiversity. *Parasitology* 106, S47-S53.
- Bezauri, J. (1993), personal communication, Amigos de Sian Ka'an, Cancun, Mexico.
- Boo, E. 1990. *Ecotourism: The Potentials and Pitfalls. 2 Volumes*. Vol. 2. WWF International, Washington DC.
- Brookshire, D.S. 1992. *Issues Regarding Benefits Bransfer*. "Benefits Transfer: Procedures, Problems and Research Needs", American Association of Environmental and Resource Economists Workshop in Snowbird, Utah, June.
- Brookshire, D. and Neill, H. 1992. Benefit transfers: conceptual and empirical issues. *Water Resources Research* 28, 651-655.

- Brown, K. 1992. *Carbon Sequestration and Storage in Tropical Forests*. Global Environmental Change Working Paper 92-24, Centre for Social and Economic Research on the Global Environment, University of East Anglia, University College London.
- Brown, K. and Adger, W. N. 1994. Economic and political feasibility of international carbon offsets. *Forest Ecology and Management*. 68
- Brown, K. and Pearce, D. W. 1994. The economic value of non-marketed benefits of tropical forests: carbon storage. In: *The Economics of Project Appraisal and the Environment* Weiss, J. (ed.). Edward Elgar, London pp 102-123.
- Brown, S. and Lugo, A. E. 1992. Above ground biomass estimates for tropical moist forests of the Brazilian Amazon. *Interciencia* 17, 8-18.
- Bruijnzeel, L.A. 1990. *Hydrology of Moist Tropical Forests and Effects of Conversion: A State of Knowledge Review*. International Hydrological Programme, UNESCO, Paris.
- Bye, R. 1993. The role of humans in the diversification of plants in Mexico. In: *Biological Diversity in Mexico: Origins and Distribution*. Ramamoorthy, T. P., Bye, R., Lot, A. and Fa, J. (eds.). Oxford University Press, New York pp 707-731.
- Bye, R., Caballero, J., Linares, E., Mapes, C., Martinez, M. A. and Mendoza, M. (1993) *Non-timber Forest Resources in Mexico - An Overview*. Report to the World Bank, Jardin Botanico, UNAM, Mexico.
- Ceballos Lascurain, H. 1988. *El Turismo Ecologico en Mexico como Instrumento de Desarrollo Socioeconomico y de Conservacion*, mimeo.
- Cervigni, R. 1993. *Biodiversity, Incentives to Deforest and Tradeable Development Rights*, GEC Working Paper 93-07, CSERGE, University College London and University of East Anglia.
- Clark, E.H., Haverkamp, J.A. and Chapman, W. 1985. *Eroding Soils: The Off-farm Impacts*. The Conservation Foundation, Washington DC.
- Cline, W. R. 1992. *The Economics of Global Warming*. Institute for International Economics, Washington DC.
- Cofer, W. R., Levine, J. S., Winstead, E. L., Stocks, B. J., Cahoon, D. R. and Pinto, J. P. 1993. Trace gas emissions from tropical biomass fires: Yucatan Peninsula, Mexico. *Atmospheric Environment* 27A, 1903-1907.
- Crutzen, P. J. and Andreae, M. O. 1990. Biomass burning in the tropics: impact on atmospheric chemistry and biogeochemical cycles. *Science* 250, 1669-1677.

- Cruz, W.D., Francisco, H.A. and Conway, Z.T. 1988. *The On-site and Downstream Costs of Soil Erosion in the Magat and Pantabangan Watersheds*. College of Economics, University of Philippines, Los Baños, Philippines.
- Dixon, R. K., Andrasko, K. J., Sussman, F. A., Lavinson, M. A., Trexler, M. C. and Vinson, T. S. 1993. Forest sector carbon offset projects: near-term opportunities to mitigate greenhouse gas emissions. *Water, Air and Soil Pollution* 70, 561-577.
- Estrada, J. W. and Ortiz Solorio, C. A. 1982. Plano de erosion hidrica del suelo en Mexico. *Geografia Agricola* 3, 23-37.
- Faeth, P., Cort, C. and Livernash, R. 1994. *Evaluating the Carbon Sequestration Benefits of Forestry Projects in Developing Countries*. World Resources Institute: Washington DC.
- Fankhauser, S. 1994. *Valuing Climate Change: the Economics of the Greenhouse Effect*. Earthscan, London in press.
- Farnsworth, N. R. and Soejarto, D. D. 1985. Potential consequences of plant extinction in the United States on the current and future availability of prescription drugs. *Economic Botany* 39, 231-240.
- Fearnside, P. M., Leal, N. and Moreira Fernandes, F. 1993. Rainforest burning and the global carbon budget: biomass, combustion efficiency and charcoal formation in the Brazilian Amazon. *Journal of Geophysical Research* 98, 16733-16743.
- Fisher, A. C. and Hanemann, W. M. 1985. *Option Value and the Extinction of Species*. mimeo, California Agricultural Experiment Station, Berkeley, Ca.
- Gutman, P. 1992. *Venezuela Natural Resources Management Project: Costs and Benefits of the Project*. World Bank, Washington DC.
- Haines, A. 1993. The possible effects of climate change on health. In: *Critical Condition: Human Health and the Environment* Chivian, E., McCally, M., Hu, H. and Haines, A. (eds.). MIT Press, Cambridge Mass. pp 151-170.
- Hanley, N. D. and Ruffell, R. J. 1993. The contingent valuation of forest characteristics: two experiments. *Journal of Agricultural Economics* 44, 218-229.
- Henry, C. 1974. Investment decisions under uncertainty: the irreversibility effect. *American Economic Review* 66, 1006-1012.
- Herman, H. 1993. personal communication, Pronatura, Mexico City.
- Holmes, T. P. 1988. The offsite impact of soil erosion on the water treatment industry. *Land Economics* 64, 356-366.

- Houghton, R. A., Skole, D. L. and Lefkowitz, D. S. 1991. Changes in the landscape of Latin America between 1850 and 1985: II Net release of CO₂ to the atmosphere. *Forest Ecology and Management* 38, 173-199.
- Iltis, H. H. 1988. Serendipity in the exploration of biodiversity: What good are weedy tomatoes? In: *Biodiversity* Wilson, E. O. (ed.). National Academy Press, Washington DC pp 98-105.
- Krupnick, A. J. 1993. Benefit transfers and valuation of environmental improvements. *Resources* 110, Winter 1993, 1-7.
- Laird, D. 1993. personal communication, Mexico DF.
- Maas, J. M. and Garcia-Oliva, F. 1990. La conservacion de suelos en zonas tropicales: el caso de Mexico. *Ciencia y Desarrollo* 15(90), 21-36.
- Maas, J., Jordan, C. and Sarukhan, J. 1988. Soil erosion and nutrient losses in seasonal tropical agroecosystems under various management techniques. *Journal of Applied Ecology* 25, 595-607.
- Maille, P. and Mendelsohn, R. 1993. Valuing ecotourism in Madagascar. *Journal of Environmental Management* 38, 213-218.
- Martinez-Menez, M. R. and Fernandez, V. J. 1983. *Jerarquizacion de Acciones de Conservacion de Suelos a Partir de Cuencas Hidrologicas*, mimeo, Mexico Distrito Federal.
- Martinez Menez, M. R., and Fernandez Villareal, J. 1984. Evaluacion de la Degradacion Especifica a Nivel Nacional a Partir de Cuencas Hidrologicas. In: *XVII Congreso Nacional de la Ciencia del Suelo in Mexico*, Sociedad Mexicana de la Ciencia del Suelo.
- Masera Cerutti, O., Ordonez, M. d. J. and Minjarez, R. D. 1992. *Carbon Emissions and Sequestration in Forests: Case Studies from Seven Developing Countries. Volume 4: Mexico*. USEPA and Energy and Environment Division, Lawrence Berkeley Laboratory, Berkeley, Ca.
- Nordhaus, W. D. 1991. To slow or not to slow: the economics of the greenhouse effect. *Economic Journal* 101, 920-937.
- Nordhaus, W. D. 1992. An optimal transition path for controlling greenhouse gases. *Science* 258, 1315-1319.
- Oldfield, M. L. 1984. *The Value of Conserving Genetic Resources*. Sinauer Associates Inc, Sunderland, Mass.
- Pearce, D.W. 1993. *Economic Values and the Natural World*. Earthscan, London.
- Pearce, D.W. and Moran, D. 1994. *The Economic Value of Biological Diversity*. Earthscan, London. (in press).

- Peters, C. M., Gentry, A. H. and Mendelsohn, R. O. 1989. Valuation of an Amazonian rainforest. *Nature* 339, 655-656.
- Principe, P. P. 1991. Valuing the biodiversity of medicinal plants. In: *The Conservation of Medicinal Plants: Proceedings of a Conference Chaing Mai, Thailand*. Akerele, O., Heywood, V. and Synge, H. (eds.). Cambridge University Press, Cambridge pp 79-124.
- Raa, T. 1983. Estudio de la erosion en la cuenca alta del Rio La Antigua, Veracruz, Mexico. *Biotica* 8, 361-380.
- Randall, A. and Stoll, J. 1983. Existence values in a total valuation framework. In: *Managing Air Quality and Scenic Resources at National Parks and Wilderness Areas*. Row, R. D. and Chestnut, L. G. (eds.) Westview Press, Boulder Co.
- Redford, K.H., and Padoch, C. (eds.) 1992. *Conservation of Neotropical Forests*. Columbia University Press, New York.
- Reid, W. V., Laird, S. A., Meyer, C. A., Gamez, R., Sittenfeld, A., Janzen, D., Gollin, M. and Juma, C. 1993. *Biodiversity Prospecting: Using Genetic Resources for Sustainable Development*. World Resources Institute, Washington DC.
- Reining, C. and Heinzman, R. 1992. Nontimber forest products in Peten, Guatemala: Why extractive reserves are critical for both conservation and development. In: *Sustainable Harvesting and Marketing of Rainforest Products*. Plotkin, M, and Famolare, L. (eds). Conservation International, Washington DC pp 110-117.
- Rosenzweig, C. and Parry, M. L. 1994. Potential impact of climate change on world food supply. *Nature* 367, 133-138.
- Ruitenbeek, J. 1989. *Republic of Cameroon: the Korup Project*. Ministry of Planning and Regional Development, Cameroon.
- SARH (Secretaria de Agricultura y Recursos Hidraulicos) 1987. *La Erosion y Conservacion del Suelo en Mexico: Realidades y Perspectivas*. SARH, Mexico DF.
- Schneider, S. H. 1992. Global climate change: ecosystem effects. *Interdisciplinary Science Reviews* 17, 142-148.
- Schramm, G. 1982. *The Economics of Soil Conservation in a Semi-Arid Country: Mexico*. School of Natural Resources, University of Michigan, Ann Arbor MI.
- SECTUR (Secretaria de Turismo) 1993. personal communication. Mexico City.
- Snook, L., Guzman, G. and Villarreal, L. 1989. *La Produccion de los Hongos Comestibles en los Bosques del Cofre de Perote*, CONACYT.

- Swanson, T. 1992. *The International Franchise Agreement Option*, CSERGE, University College London and University of East Anglia, mimeo.
- Synnott, T.J. 1993. *Forestry Subsector Study in Mexico: Diagnostic Study*, Report to World Bank (LA2), Washington DC.
- Tajbakhsh, M. 1993. personal communication, Conservation International, Washington D.C.;
- Torres, J. 1987. *Ecología y Uso de los Recursos Renovables de la Cuenca del Rio San Marcos, Tamaulipas, Mexico*, Thesis Facultad de Ciencias, UNAM, Mexico DF.
- Tobias, D. and Mendelsohn, R. 1991. Valuing ecotourism in a tropical rainforest reserve. *Ambio* 20, 91-93.
- Toledo, V. M., Batis, A. I., Becerra, R., Martinez, E. and Ramos, C. H. 1992. Products from the tropical rainforests of Mexico: An ethnoecological approach. In: *Sustainable Harvest and Marketing of Rainforest Products*. Plotkin, M. and Famolare, L. (eds.). Conservation International, Washington DC pp 99-109.
- Vásquez-Sánchez M.A., March, I. and Lazcano-Barrero, M. 1992. Características socioeconómicas de la Selva Lacandona. In: *Reserva de la Biosfera Montes Azules, Selva Lacandona: Investigación para su Conservación*. M.A. Vásquez-Sánchez and M. Ramos (eds.). Ocas. Ecosfera.
- Whelan, T. (ed.) 1991. *Nature Tourism: Managing for the Environment*. Island Press, Washington DC.
- World Conservation Monitoring Centre 1992. *Global Biodiversity: Status of the Earth's Living Resources*. Chapman and Hall, London.
- World Resources Institute 1992. *World Resources 1992-1993*. Oxford University Press, New York.