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Review Paper

The providence of nature: Valuing ecosystem services

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Abstract

Natural ecosystems provide an array of critical but largely undervalued goods and services. Because these are seldom included in benefit-cost calculations of land use change, the value of wild land development nearly always appears greater than protecting wild nature. The following paper introduces a theoretical framework within which environmental economists evaluate ecosystem services. This is followed an assessment of three types of ecosystem services with particular relevance to the developing world pharmaceutical drug development from native plants, the economics of non-timber product extraction, and the benefits and costs of ecotourism as a development strategy. We conclude with an overview of recent attempts to provide a global estimate of the value of nature's services.

Key words: *environmental economics, ecosystem services, pharmacopoeia, non-timber products, ecotourism*

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Introduction

Ecosystem services include those processes and conditions within which nature sustains and otherwise meets the needs material and otherwise of humankind. These include tangible goods, such as timber, fiber, fuel wood, foods, and medicines, as well as the array of environmental services that support life on earth, such as water purification, carbon dioxide absorption, biogeochemical cycling, and many others. In spite of the obvious value of these goods and services in supporting and improving the human condition, many of these values are customarily ignored in the course of development projects. Even when cost-benefit analyses are incorporated into planning and decision-making, many of the less tangible services provided by ecosystems are omitted from the calculus. The result of these omissions is that the economic benefits of development, such as replacing forest with pasture, or draining wetland for agricultural expansion, nearly always appear to outweigh the costs of environmental protection.

In recent publications, (Daily, 1997) attempted to correct this omission by synthesizing the vast array of scattered publications dealing with the economic valuing ecosystem services. They recognize, however, that this endeavor is fraught with difficulties (Gatto and DeLeo, 2000). For example, assigning an economic value to many of these life-support systems may seem too 'trivial' for consideration how meaningful, for example, is it to identify the value of oxygen production by plants to human life? Moreover, unlike traditional goods and services whose values are captured in commercial markets, many ecosystem services seem to defy rational accounting. For example, in South America the iroko tree is considered the 'sacred' dwelling place of an ancient forest god (Voeks, 1997). Is it a useful endeavor to attempt to monetize the value of people's religious beliefs? Economic evaluations of nature are seen by others, particularly those that ascribe to a 'deep ecology' view, as part and parcel to the problem, rather than the solution. Is it acceptable to value the existence of a nondescript species, such as a spider or flea, over a more visually and emotionally appealing species, such as a tiger or elephant? In spite of these conflicting issues, these authors contend that the gravity of the environmental problem demands, at least, that an attempt be made at quantifying these benefits at the global level.

The objectives in this paper are to introduce the concept of valuing ecosystem goods and services. After examining the theoretical framework within which environmental goods and services are valued, we review three areas of nature valuation with relevance to the developing world. These include:

- The value of folk medicinal plants in pharmaceutical drug development;
- The value of petty resource extraction from natural landscapes;
- The value of ecotourism as a development strategy for developing countries; and
- Finally, summarizing the work of (Daily, 1997), an estimate of the combined global value of ecosystem goods and services is provided.

Theoretical framework

In order to evaluate environmental goods and services, the key is to recognize that the relevant measure is the change in damage reductions brought about by a policy. These changes are called incremental benefits and can be defined as the reduction in health, ecological, and property damages associated with an environmental policy initiative. To identify these incremental benefits, the analyst must compare the actual or expected benefits to society after some policy is implemented to a baseline of current conditions.

These benefits are of two kinds primary and secondary. A primary environmental benefit is a damage reducing effect that is a direct consequence of implementing an environmental policy. Examples include human health benefits, a more stable ecosystem, and improved aesthetics where they all are direct outcome of environmental policy. Secondary environmental benefits are characterized as providing an indirect gain to society associated with the implementation of environmental policy. Examples could include higher worker productivity resulting from the primary benefit of improved health.

The overall environmental benefits evaluations include (but are not necessarily limited to):

- Economic values (e.g.: improved soil productivity and increased value of other natural resources, increase in international tourism),
- Environmental opportunities (e.g.: increased recreational values of lakes, rivers, beaches and forests for the population), and
- The value of healthy life and well being of the population (e.g. life saved, avoidance of pain and suffering from illness, cleaner environment, etc,).

In this paper the value of environmental goods and services is frequently expressed as a percentage of GDP in order to provide a sense of magnitude. It is also often useful to compare these values to GDP in order to assess their relative magnitude over time. If the value of environmental benefits as a percentage of GDP is growing over time, it suggests that the welfare increase from environmental improvement is growing faster than GDP.

The environmental benefits are valued conceptually since there are no explicit markets for environmental quality. Thus, we need to draw inferences about how society derives value or utility from the environmental goods. From a purely conceptual point, it is generally recognized that the society derives utility from environmental quality through two sources of value, user value and existence value.

User value is the utility or benefit derived from physical use or access to an environmental well which consists of direct user value and indirect user value. Direct user value is derived directly from consuming services provided by an environmental good. Indirect user value is derived from indirect consumption of an environmental good. Existence value on the other hand is the utility or benefit received from an environmental good through its continuance as a good or service. Total valuation of environmental quality is the sum of User Value and Existence Value, which is referred to as "Preservation Value".

Methodological Approaches to Measuring Environmental Benefits

The process of estimating the value of environmental amenities involves a three-step process:

- Quantification of environmental amenities (e.g.: monitoring of ambient air quality, river/lake/sea water quality, soil pollution),
- Quantification of the consequences of a change in the amenities (e.g.: changes in soil productivity, changes in forest density/growth, reduced natural resource based recreational activities, reduced tourism demand, health impacts of air pollution); and

- Monetary valuation of the consequences (e.g.: estimating the cost of soil productivity losses reduced recreational values, ill health).

Environmental science, natural resource science, health science and epidemiology, economics (and frequently other sciences) are often used to quantify environmental degradation/conditions and its consequences. For valuation of the consequences, environmental economics and natural resource economics are applied. This paper has attempted to collate available information on the quantification of environmental valuation in the world, and information that has been available on the consequences of degradation.

In order to materially estimate the environmental qualities of various areas of the environment, the analysis and estimates are generally organized by means of the following categories: water; air; soil; waste; coastal zones and cultural heritage and the global environment.

Techniques that assess responses immediately related to environmental changes are broadly categorized as Direct and Indirect Methods. The Direct Method uses Political Referendum and Contingent Valuation Methods. Indirect methods are those that examine responses not about the environmental good itself, but about some set of market conditions related to it. This method uses Averting Expenditure, Travel Cost, and Hedonic Pricing Methods.

Direct estimation methods under the behavioral linkage approach

The Behavioral Linkage approach is based on the observations of behavior in the markets or consumer responses about hypothetical markets for environmental goods. This method estimates the environmental benefits according to responses or observed behaviors directly tied to environmental quality. There exist two broad categories in this approach:

1. The political referendum method

This method uses voter responses to political referenda on environmental issues to make inferences about society's valuation of the associated benefits. Inferences drawn from a single referendum provide only a qualitative assessment about environmental benefits. To use the political referenda data to quantify incremental benefit, the analyst must monitor voter's reaction to a series of proposals that will convey how changes in environmental quality are valued. This method is often used to confirm findings of other estimation approaches or to test the predictive power of methods that use hypothetical markets.

2. The contingent valuation method (CVM)

Economists consider the appropriate value of environmental amenities to be what an individual would be willing to pay to preserve it. This should reflect the value of foregone consumption and leisure time and the loss of contact with loved ones. Willingness to Pay (WTP) can be estimated using the contingent valuation method (CVM). CVM estimates the WTP or willingness to accept (WTA) for a change in the quantity and/or quality of a good by using survey techniques (Mitchell and Carson, 1989 and Hoevenagel, 1994). In the questionnaire a hypothetical change is described and the respondents are asked directly for their WTP or WTA for the proposed change.

The CVM is used when the market data are unavailable or unreliable. Surveys are employed to inquire about individual's willingness to pay for some environmental policy initiative. This method is favored by researchers of its applicability to variety of environmental goods and services because of its capacity to assess existence value as well as user value. The following are some of the applications of CVM.

- Measures society's WTP for water quality improvements
- Incremental benefits from air quality
- Value ecological benefits, such preventing endangered species.

Because CVM is a costly and complex method, studies have been conducted in only a limited number of countries for a limited number of environmental goods and services. In the United States and Europe numerous CVM studies have been conducted on the WTP for whole array of environmental amenities. Where WTP/WTA are not available for a particular country, one can estimate these values for risk reduction through "benefit transfer" of WTP studies performed outside that country.

Benefit transfer is an application of monetary values from a particular valuation study in one area to a policy decision setting in another geographic area (Navrud, 1999). When transferring values it is important to know when data from other studies can be used and under what conditions. The value that people attach to environmental improvement depends on the type and magnitude of risk (low probability, high impact), the extent to which the risk is experienced voluntarily, on cultural settings, income, and the futurity of the risk. The most important factors for applying benefit transfer are the level of real per capita income, represented by purchasing power parity (PPP) per capita income, and the income elasticity of WTP. Where estimates of WTP for environmental amenities are not available, it is therefore necessary to transfer these estimates from countries where WTP studies have been conducted. When extrapolating estimates of WTP from one country to another, adjustments must be made for the effect of income on WTP. For instance, in transferring estimates from country A to country B the formula used is:

$$WTP_B = WTP_A\ [Income_B/Income_A]^{3}$$

Where ε represents the income elasticity of WTP (the percentage change in WTP corresponding to a one percent change in income). It should be acknowledged that there is considerable uncertainty regarding estimates of the income elasticity of WTP, as well as uncertainty regarding the estimates of WTP themselves. This uncertainty can be handled in two ways. First, several estimates of the income elasticity of WTP such as 1.0, and 0.4 are used. Holding WTP_A constant, the 0.4 elasticity results in a larger WTP estimate for the country in question than the 1.0 elasticity. Indeed, when WTP estimates from the United States are transferred to another country using Purchasing-Power-Parity adjusted Income; an income elasticity of 0.4 implies a very large WTP for that country that is about the size of WTP in the US. Therefore WTP estimates based on an income elasticity of 0.4 as upper bound estimates, and estimates based on an income elasticity of 1.0 as central case estimates. Second, to handle uncertainty about the size of WTP, a conservative, lower bound estimates of the value of environmental amenities are being presented.

Indirect estimation methods under the behavioral linkage approach

The Behavioral Linkage approach explores the relationship that exists between the implicit prices of environmental characteristics that differentiate closely with related products. There are several methods where the marginal implicit price of environmental goods or services can be estimated.

1. Averting expenditure method (AEM):

The AEM method uses changes in an individual's spending on goods that are substitutes for a cleaner environment to estimate the value of environmental qualities and services. The motivation here is that exposure to pollution causes damages that negatively affect an individual's utility. There are two critical assumptions:

a) A systematic relationship can be identified between the quality of the overall environment and that of an individual's personal environment.

b) Goods may act as substitutes for environmental quality.

One drawback of AEM is joint-ness of production. Whereas some averting expenditures yield benefits beyond those associated with a cleaner environment. Although there are some disadvantages of using AEM, this approach has been used to value statistical life of wearing seat belts in automobiles in an effort to reduce mortality risk.

2. Travel cost method:

Travel Cost Method (TCM) uses the complementary relationship between the quality of a natural resource and its recreational use value. A disadvantage of using TCM is that it is capable of estimating only user value and not existence value. Due to this limitation, the TCM is commonly used only to estimate the value of improvements to water bodies used mainly for recreational activity.

3. Hedonic pricing method (HPM):

HPM uses the estimated hedonic or implicit price of an environmental attribute to assign value to policy driven improvements in the environment. It is based on the theory that a good or service is valued for the attributes or characteristics that it possesses. HPM uses regression analysis to determine the implicit price of any environmental variable. Hedonic pricing estimates the WTP/WTA through;

- The difference in the value of the same property located in different areas with different environmental risks (property value differential); or
- The wage differential people are willing to pay (or accept) for a decrease (or increase) in risk of death related to a job.

This method of evaluation is used only due to the fact that it approaches the problem of monetizing incremental benefits in a logical way, directly using market prices. Unfortunately it relies on a fairly complicated empirical model. Also the model calls for extensive data or product characteristics, which are often unavailable or incomplete. HPM has been used for estimating a variety of pollution control benefits.

In the following sections we present several approaches to estimating the value of environmental goods and services in global production. Our purpose is to present some economically logical valuations that might be included in future green GDP accounts. Most of the estimates are based on the assumption that a hypothetical market exists where these environmental amenities are exchanged and the population is being charged for its use. Zero on the lower end and gross world output at the upper end bound all of these estimates logically. The underlying message of this calculation is clear; including the value of ecosystem goods and services would dramatically alter current GDP estimates.

Valuing local plant pharmacopoeias

In the last few decades there has been a renewed interest in the healing properties of nature, in particular the social and economic benefits of bioprospecting for pharmaceutical drug plants. It is well known that plants maintain a host of defensive secondary compounds saponins, phenols, terpenes, alkaloids, and others and that many are bioactive in humans. Over the centuries, many plant compounds have been tested and ultimately developed into modern pharmaceuticals. Quinine derived from the bark of the Peruvian cinchona tree (Cinchona ledgeriana) is used to treat malaria. Pilocarpine from the Brazilian herb (Pilocarpus jaborandi) is used to treat glaucoma. Diosgenin from Mexican yams (Diascorides ssp.) is used as a female contraceptive. In the most celebrated example, the alkaloids vincristine and vinblastine derived from the Madagascar periwinkle (Catharanthus roseus) were developed into a cure for Hodgkin's disease and childhood leukemia (Balick and Cox, 1996 and Soejarto and Farnsworth, 1989). More recently, several plant derived products, including the protein MAP30 from the bitter mellon (Momordica charantia) and prostratin from the Samoan mamala tree (Homalanthus nutans) have shown anti-HIV activity in in–vitro studies Cox (2000); Kell (2001) and Myers (1997) estimates that 30,000 American lives are saved each year by anti-cancer drugs derived from plants.

The developing world represents a particularly rich source of potential medicinal species. Secondary compounds are more concentrated in tropical regions, as is the biological diversity of plant species (Levin, 1976 and Pitman and Jorgensen, 2002). Just as important, the traditional societies that sustain these cognitive relations with nature are much more likely to survive in developing as opposed to industrial countries.

Economic projections of the potential value of medicinal plant resources, both to private pharmaceutical corporations and to society in general, underscore the value of this endeavor (Adger, *et al.*, 1995 and Myers, 1997). According to (Soejarto and Farnsworth, 1989), twenty five percent of all prescription drugs sold in the U.S. in the 1980s contained compounds that were extracted from plants, totaling over US $8 billion in annual retail sales. A few years later recalculated this figure. Noting again that one-quarter of drugs currently on the US market were originally derived from plant compounds, and multiplying this by the current prescription sales in the US (US $62 billion/yr), he estimated that the value of plant-derived drugs averages US $15.5 billion/yr.

Principe (1991) reconsidered these calculations in terms of societal benefits of potential new plant-derived drugs. First, he estimated that roughly 500,000 Americans contract cancer per year. He then notes that anti cancer drugs, of which 40% are of plant-derived origin; cure about 15% of these cases. This yields about 30,000 Americans per year who owe their continued existence to plant-derived drugs. He then considered the “value of life” of each of these individuals, and used the average figure of US $8 million. Multiplying this figure by the 30,000 saved lives yields a total economic value to American individuals of US $ 240 billion per year.

The economic value of potential drug plants can be examined as well by considering individual drug discoveries. In the 1960s, the Eli Lilly Pharmaceutical Corporation began examining the pharmacological properties of the Madagascar periwinkle (Catharanthus roseus). The discovery of the efficacy of two of its 76 alkaloids vincristine and vinblastine in the treatment of acute lymphoblastic leukemia, lymphosarcoma, Hodgkin’s disease, and other tumors, was a major catalyst for renewed interest by pharmacological companies in plant derived medicines. The idea to explore the medicinal properties of this particular species was provided by a traditional healer, who recommended its use to treat diabetes (Balick and Cox, 1996). Sales from this single drug by Eli Lilly are estimated to generate US $100 million per year.

Finally, what is the potential value of the many as yet undiscovered drug plants? The case of tropical forests species is instructive. It is estimated that there are between 310,000 and 422,000 plant species on Earth (Pitman and Jorgensen, 2002). Of this total, roughly 125,000 are thought to inhabit tropical forest landscapes. On average, three plant parts (usually leaves, bark, and roots) per species are tested. There are, on average, 2 extraction methods used for each plant part, yielding a total number of plant extractions of 750,000 total extractions (125,000 x 2 x 3). Pharmacological screens of plant extractions average between 50 and 75. This produces 38 to 56 million possible screens from the total tropical flora of the world. On average, between one in 50,000 and one in one million screens produces a commercial drug. Applying this success rate to the total number of possible screens (38-56 million) yields a general figure of roughly 375 commercially valuable species waiting to be discovered. There have, however, already been 47 drugs produced from tropical species. Subtracting these previous discoveries from 375 yields an estimated 328 yet to be discovered pharmaceuticals. Including the cost of research and development, marketing, distribution, and interest rates, the estimated economic value of each of these undiscovered species is US $ 94 million (Mendelsohn and Balick, 1995).

As noted by many ethnobotanists, these potential drug discoveries are threatened by an array of factors. Habitat loss has been linked to decreasing access to traditional plant medicines in Samoa, Kenya, eastern Brazil, (Cox, 1999; Jungerius, 1998; Voeks, 1997). In other locations, such as Sierra Leone, Cameroon, and India, valuable medicinal taxa are declining due to excessive plant extraction to supply national and international markets (Anyinam, 1995; Lebbie, and Guries, 1995; Pandey and Bisaria, 1998). The most pressing threat to medicinal plants and their knowledge profiles, however, appears to be declining medicinal knowledge among rural communities (Cox, 2000). Religious conversion (Caniago, and Siebert, 1998; Voeks and Sercombe, 2000), entrance of western medicine (Milliken, *et al.*, 1992; Urgent, 2000), economic improvement (Benz, *et al.*, 2000; Voeks and Nyawa, 2001), and enhanced access to formal education (Voeks and Leony) have all been linked to declining knowledge of nature.

Economics of petty resource extraction

Petty resource extraction represents one of the least explored land use options for developing countries. It is based on the idea that collection of wild, non-timber products by rural people fruits, nuts, latex, fibers, rattans, medicinal, and others represents a viable alternative for natural area protection. Long perceived as a symptom of ‘underdevelopment’, and reflective of past boom-and-bust economic cycles, petty extractive activities are most often viewed by the developing world as a form of economic retardation and backwardness.

Beginning in the 1980s, environmental scientists and economists began to reconsider the possible value of the "extractive option" for nature conservation. Most of these efforts have been directed at tropical countries, where traditional extractive activities have a long pedigree, and where ongoing environmental destruction is acute. The reasoning is that, under the best of circumstances, petty extraction:

- Generates revenue at the local and national level,
- Leads to minimal levels of environmental damage,
- Maintains and supports the traditional livelihoods of local rural populations, and
- Encourages local people to serve as de facto nature stewards.

An example of this activity comes from the eastern forests of Brazil, where Voeks (1996a) investigated the ecology and extractive economy of the piassava palm (Attalea funifera). This species has supplied durable leaf fiber for the production of ropes, roofing thatch, and brooms and brushes for at least two centuries. Although originally collected by cutting and killing the palm, during the 20th. century forest collectors switched to a sustainable method of removing fiber on an annual basis. This activity appears to have minimal impact on forest diversity. A study carried out in a single piassava extractive area Voeks (1996b) revealed a high level of floristic diversity (Simpson D_s = 0.78). Moreover, economic revenue had steadily climbed over most of this century. From a low of roughly US $200,000 in sales in 1910, passive production had climbed to nearly US $ 20 million by 1990.

The most successful example of the role of extraction in nature conservation comes from Amazonian Brazil. Since the mid-19th. century, this region has been prized for its natural population of Brazilian rubber trees (Hevea brasiliensis). Many thousands of rural rubber tappers base their livelihoods on the collection and sale of latex from the forest. Responding to increasing levels of forest removal for the creation of cattle ranches, rubber tappers and environmentalists encouraged the Brazilian government to establish 'extractive reserves'. This proposal was finally given serious attention after the assassination of Chico Mendez, leader of the rubber tappers, by a local cattle rancher.

Today there are four other rubbers extractive reserves, where latex and extractive products continue to support the local population, but where forest removal is prohibited. There are a limited number of economic studies on the viability of extractive economies. In a classic study carried out in Peru, Peters, *et al.*, (1989) and censuses the economically valuable extractive products in a one-hectare plot of forest. Seventy-two species had market value 60 timber species, 11 food species, and one latex species. Utilizing the mean retail value of the non-timber extractive products, including the cost of labor and transportation, they calculated that the net present value (NPV) of fruit and latex collection was US $6,330 per hectare of forest. Although the immediate value of timber extraction was higher, the long recovery time necessary for forest trees to grow back to harvestable size translated to a relatively low NPV of US $ 490. Although there were methodological errors in this calculation, and non-use ecosystem good and services were omitted from the calculation, it suggests nevertheless that extraction should be considered as an economic option to habitat destruction.

In another economic analysis, this in Belize Balick and Mendelsohn (1992) examined the extractive value of plants used by locals in traditional healing and sold in local markets. They collected the medicinal species in two small plots, one of 0.28 ha, the other of 0.25 ha. The two sites yielded 86.4 kg and 358.4 kg (dry weight biomass), respectively. Projecting this to a full hectare yielded 308 kg and 1433 kg, respectively. The estimated gross revenue from these two sites was US $ 864 and $ 4,014, respectively. Including estimated labor and transportation costs into the calculation yielded values of US $ 564 and $ 3,054 per hectare. The authors compared these values to alternative land uses clearance for agriculture (corn, beans, and squash), and pine plantation development, which were estimated to yield US $339 and $3184 per hectare, respectively. The results of this study suggest that allowing natural areas to be deployed as medicinal plant extraction zones compares favorably with more destructive forms of land use. Godoy, *et al.*, (1993) reviewed economic analyses of extractive enterprises done to date, and found them lacking in several ways. They note that each study uses different economic assessment methods, none includes the value of both animals and plants, and all assume without evidence that these activities are environmentally sustainable. They suggested the following methods: randomized village samples, accurate biomass weighing systems, photographing species that cannot be collected, and using GPS and GIS techniques for field mapping of extractive zones. Regarding economic analysis methods, they recommended: using actual local market value of goods (including barter value), distinguishing goods that are consumed in the village from those transported to markets, adjusting for relevant taxes and subsidies, including cost of material, labor, and discount rate, and including value of nonuse ecosystem services in the calculation.

In a later publication, incorporated most of these suggestions in a study of extraction in rural Honduras villages. They worked in two villages, identifying the value of fish, game, and other forest products gathered in the vicinity. The two villages averaged US $91,041 and $ 3,920, respectively, per year in extractive products. Calculating this per unit hectare yielded figures of US $ 2.50 and $ 9.05. These values are much lower that those achieved in earlier studies, suggesting that other studies may have over-valued the extractive enterprise in their respective areas. It also underscores the economic motivation for local populations to switch to more destructive land uses, such as agriculture and forestry, which produce higher immediate economic returns.

Whether or not petty extraction represents a viable alternative to destructive land use is problematic. Research on the topic has produced mixed results. Importantly, none of these studies incorporated ecosystem values, such as carbon sequestration, erosion control, and others, that tend to benefit the global rather than local community. If non-use ecosystem values are to be incorporated into rural economic assessment, it seems clear that global stakeholders, who are likely to accrue most of its benefits, must bear some of the costs of protecting rural ecosystems in the developing world.

Ecotourism and nature's economic services

Ecotourism is widely touted as a viable development strategy for the developing world. It can be defined as "responsible travel to natural areas that conserves the environment and sustains the well-being of local people" (Honey, 1999). In addition to appreciating the natural qualities of the region dramatic landscapes, native wildlife, and endemic plants visitors are often drawn as well to observe local cultural traditions. While often based on romanticized notions of the relations between rural people and nature, ecotourists nevertheless often wish to observe how traditional societies live with nature their subsistence agricultural methods, hunting and fishing techniques, religious ceremonies, and healing practices.

The allure of ecotourism for developing countries is that:

- It requires minimal infrastructural investment,
- It causes limited environmental impact compared to other options, and
- It generates significant foreign exchange.

Indeed, the tourist industry has exploded in recent decades. In 2000, there were an estimated 702 million international tourists, generating an estimated US $ 621 billion in revenue. Roughly 8% of the world's population is employed, directly or indirectly, in tourism-related activities. Ecotourism, which represents the fastest growing tourism sector, generates an estimated US $ 50 billion in global revenue in 2000 (Fennell, 1999). In Tanzania, where ecotourism represents the largest source of revenue, gross receipts totaled US $ 322 million in 1996. Kenya realized $ 502 million in gross receipts in 1997, while South Africa received $2.2 billion in earnings in 1995 (Honey, 1999). Clearly, there is a significant economic motive to embrace ecotourism development.

Under the best of circumstances, ecotourism provides benefits at the local, regional, national, and international levels. At the local level, people benefit as visitors purchase locally produced foods and crafts, lodge in locally owned hostels, employ local guides, and otherwise encourage local people to remain in rural settings rather than migrating to cities. At the regional level, jobs are produced and locally produced goods are marketed. At the national level, tax revenues and user fees are collected, foreign exchange is generated, and capital investment is captured rather than exported to the developing world. Finally, because ecotourism encourages nature protection in the developing world, globally significant ecosystem services are protected rather than destroyed.

In spite of these potential economic benefits, ecotourism development is also accompanied by a host of social and economic challenges. For example, Costa Rica established the Tortugeira National Park in the 1970s in order to stimulate ecotourism and to protect rare and endangered sea turtles that nest along the immediate coast. Although these environmental and economic expectations were realized, the impact on local communities was mostly negative. Land speculation and the rising cost of living forced most of the original local population to migrate away from the area (Place, 1991). In India, national park expansion to meet the needs of ecotourists has occurred at the expense of local farmer access to land.

Moreover, 'leakage' or revenue plagues many ecotourism efforts. While the host country bears most of the costs of ecotourism, it is often foreign companies that realize most of the profits. This is particularly true as more and more ecotourists opt for package tours organized in their home country staying in foreign-owned hotels, eating and drinking imported luxury goods, and employing foreign guide services. Culture change can be a particularly insidious dimension of ecotourist development. Malaysia, Thailand, and elsewhere, tourist attraction to more exotic elements of the local religion and culture has led a form of 'cultural co modification'. Tribal societies in Thailand dress up in traditional attire to meet the expectations of visitors, while in Malaysia and Brunei Darussalam the interior tribal groups perform dances and other cultural activities at times and place to meet the needs of tourists. Over time, the cultural significance of long-established rituals and ceremonies is defined more by its attraction for visitors than by its original cultural meaning.

National efforts to better capture foreign revenue include: collection of user fees (e.g. park entrance), concession fees charged to tour companies, royalties from souvenir sales, taxes, and donations. Bhutan, for example, charges US $200 per day for foreign visitors, and limited annual visitation to only 5,000 visitors. Rwanda charges a flat rate of US $ 250 for a sixty-minute visit to their mountain gorilla preserve. But these extreme models are not likely to be repeatable in less sought-after locales.

The small Central American nation of Costa Rica has banked heavily on ecotourism as a means of advancing nature protection and generating sorely needed foreign revenue. Possessing a high degree of natural values, from coral reefs and beaches to tropical rainforests and highland cloud forests, Costa Rica also has the burden of a high level of rural poverty and unemployment. Since the 1990s, the principal national revenue has shifted from coffee cultivation to ecotourism. With a total population of only three million people, Costa Rica now hosts over one million tourist visitors per year (Honey, 1999).

The evolution of one of its various parks, Monteverde National Park, underscores the economic impact of tourist development. With on 471 visitors in 1974, the park had increased visitation to 26,600 by 1990. Utilizing the travel cost method to measure the economic value of ecotourism, Menkhaus and Lober (1996) determined that the cost of travel for ecotourists ranged from a low of US $800 to a high of $ 8,000. Multiplying the average travel cost to ecotoursts, US $1150, and assuming that ecotourists visited other areas of Costa Rica, the determined that the value of ecotourism to Monteverde National Park was on the order of US $ 4.5 million per year.

In the Cuyabeno Wildlife Reserve in Ecuador, Wunder (2000) examined economic benefits to various local communities. Presently, about 5000 ecotourists arrive at the protected area per year. Using semi-structured interviews, demographic studies, and cash and subsistence evaluations, Wunder (2000) examined the relative success of five separate ethnic groups in capturing capital. Unlike other studies, this author discovered that significant economic benefits were accrued by the various local groups. One group realized US $49,430 during a single year, representing 100% of their total cash income, while another group received $ 31,753, representing 97.5% of their cash income for the year. In this case, ecotourism development led to positive economic benefits for the local communities.

As a strategy for developing countries, ecotourism provides divergent prospects and problems. In many cases, significant levels of foreign revenue are realized at the local and national level. Nevertheless, strategies need to be pursued in order to diminish the effects of revenue leakage. The social and cultural impacts

Nature's goods and services: A global assessment

Economic assessment of the global significance of ecosystem services requires a division of the Earth's ecosystems into a logical set of geographical units. To simplify the bewildering diversity of ecosystems, aquatic and terrestrial, the approach taken in is to work at the biome level.

Coastal and marine biomes include:

- Open ocean,
- Estuaries,
- Sea grass beds,
- Coral reefs, and
- Continental shelves.

Terrestrial biomes included:

- Tropical forest,
- Temperate/boreal forest,
- Grassland/rangeland,
- Wetlands,
- Lakes/rivers,
- Deserts, and
- Tundra.

Some of these ecosystems have been the subject of environmental economic analysis; others have received no attention whatsoever. This obviously biases the final results, and should serve as motivation to expand research efforts into these underrepresented subsets of nature.

Although ecosystem services overlap considerably, for convenience these are reduced to seventeen classes of goods and services. These include:

- Gas regulation (e.g. maintaining the CO2/O2 balance);
- Climate regulation (e.g. precipitation regimes);
- Disturbance regulation (e. g. flood control);
- Water regulation (e.g. irrigation);
- Water supply (e.g. access to potable water);
- Erosion control (e.g. loss of topsoil);
- Soil formation (e.g. rock weathering);
- Nutrient cycling (e.g. nitrogen fixation);
- Waste treatment (e.g. pollution control);
- Pollination (e.g. crop reproduction);
- Biological control (e.g. sustaining keystone species);
- refugia (e.g. waterfowl habitat);
- Food production (e.g. fishing);
- Raw materials (e.g. lumber);
- Gene resources (e.g. locally-endemic cultigens);
- Recreation (e.g. ecotourism); and
- Cultural (e.g. aesthetics).

What follows is a sample of the ecosystem goods and services that are rendered by nature, a sample of the threats to these values, and an attempt at economic valuation of each.

1. Open oceans

Open oceans represent the largest of Earth's biomes, with an area of 33,200 ha x 10^8. These areas are particularly important on a global scale in regulating gas exchange. This includes especially the production of oxygen from surface plankton; as well a sink for carbon dioxide, the principal compound involved in anthropogenically forced global warming. Open oceans also provide important zones of nutrient cycling, particularly for nitrogen and phosphorus. Of course, the ocean is also a major contributor of fish to the global market place. The estimated economic value of these goods and service is US $252/ha/yr. Multiplied by the total area of open oceans; this translates to an annual value of US $8.3 billion.

1. Coastal marine environments

The interface between land and water represents an especially important resource and ecosystem service zone. Upwelling zones, such as off the coast of Peru, Namibia, and California provide the most productive commercial fish resource zones in the world. These zones are also noted for their recreational value to boating, swimming, surfing, and sport fishing. Coral reefs likewise represent a high value material and cultural resource in the coastal zone. They are important sources of waste treatment, biological control, recreation, and research. They are also important sources of commercial fish and lobster, including aquarium fish. Although often harvested by unsustainable means using dynamite and cyanide poisoning, the aquarium fish trade is estimated to yield between US $20-40 million dollars in revenue per year (Hoagland, *et al.*, 1995). Summing the value of these and other coastal environments yields an estimated value of US $ 4,052/ha/yr, or a total of US $12.3 trillion dollars per year for all coastal marine ecosystem goods and services.

2. Tropical forests

Tropical forests cover roughly 1,900 ha x 10^8. Given their high levels of plant productivity and extreme levels of biodiversity, this biome generates significantly valuable ecosystem services. They are especially important in terms of climate regulation, erosion control, nutrient cycling, raw materials (especially hardwoods), and tourism. Deforestation in the tropical zone has been implicated in global warming, due to release of carbon dioxide from burning, as well as regional shifts in rainfall, evapo-transpiration, and temperature. Krutilla (1991) used the replacement cost method to estimate the economic value of tropical forests as sinks for carbon dioxide. He determined that replacement costs for all tropical forests would run to about US $223 billion per year. Combining these values with the plant and animal existence values, tropical genetic resources are estimated to be worth US $41 billion dollars per year. The total economic value of all tropical forest goods and services averages US $3.8 trillion per year.

3. Temperate/Boreal forests

Temperate forests occur from subtropical zones to the edge of the arctic. They cover an estimated 2,955 ha x 10^8. Primary ecosystem services include climate regulation, waste treatment, food production, recreation, and forest raw materials. Although often managed under conditions not considered to be sustainable on a long-term basis, most temperate forests are managed with this objective. On a global scale, the economic value of timber resources alone is estimated at between US $10 and $73/ha/yr. Calculated for all timberlands, the global economic value of timber harvest is roughly US $ 26 billion per year. This figure included willingness to pay figures for recreational forest habitat. determined, for example, that the average California resident was willing to pay US $73 to protect the forest habitat of the northern spotted owl. This translated to a statewide figure of US $760 million, far more than the estimated market value of the timber. In this case, endangered species protection appears to outweigh the public's interest in raw materials. Taking into consideration all of the economic goods and services provided by temperate zone forests, their global value is placed at US $ 894 billion per year.

4. Grasslands/Rangelands

Grasslands and associated shrub lands comprise roughly 3,989 ha x 10^8. These are located mostly between 20^0 and 45^0 north and south latitude. Their principal ecosystem services include erosion control, food production, waste treatment, and nature tourism (in Africa). Given the high productivity of the soils, mostly moll sols, this biome represents the breadbasket of many civilizations. Burke, *et al.*, (1989) examined the economic value of grasslands as sinks for carbon dioxide. They determined that the average grassland that was converted to agriculture lost the ability to absorb 1.0 kg/m of carbon dioxide. Assuming a cost of CO^2 emissions (as a factor in global warming) of US $ 0.10/ha, they estimated the global value of CO^2 fixation by grasslands at US $7 billion per year. Including all relevant ecosystem services, grasslands are valued at US $906 billion per year.

5. Wetlands/Floodplains

Wetlands and floodplains represent a particularly important source of nature's services. Although constituting only 165 ha x 108 ha in area, these ecosystems provide a host of essential environmental values. These include gas regulation, waste treatment, environmental disturbance regulation, water supply, wildlife refugia, recreation, and others. The presence of riparian vegetation along streams and rivers, for example, dramatically diminishes the impact of natural flood cycles. In the United States, the estimated economic value of the avoided costs of flood control damage reaches US $7,240/ha/yr. Wetlands are equally important as sources of natural pollution control, and as refuges for endangered and threatened plants and animals. Pollution control services of wetlands in the United States are estimated at US $1,659/ha/yr. The total global value of wetlands and floodplains is estimated to be US $4.9 trillion per year.

6. Lakes and rivers

Inland lakes and rivers are often centers of human population. Although they cover only 200 ha x 10^8 of the Earth's surface, they include an array of essential goods and services. These include water regulation, water supply, waste treatment, recreation, and food. These ecosystems have in many cases suffered massive alteration, often dramatically diminishing their natural services. Once representing an important commercial fishery, the Aral Sea has lost 60% of its area in the last 30 years due to irrigation withdrawal. Lake Chad in West Africa has suffered a similar fate, with withdrawal for irrigation reducing the area extent by over 90% in the previous two decades. Considering all relevant environmental services, lakes and rivers are calculated to generate on average US $1.7 trillion annually.

7. Deserts and Tundra

Deserts and tundra cover 1,925 ha x 10^8 and 743 ha x 10^8, respectively. They clearly provide significant environmental services; however there have been no attempts to date to quantify them. They are thus omitted from the global calculation.

Total value of nature's services

Combining the calculated value of ecosystem goods and services for all the world's biomes yields a mean estimate of US $ 33 trillion/yr. This figure ranges from a low of US $16 trillion/yr to a high of US $54 trillion/yr. Comparing it to total world GNP reveals the significance of this sum. Using 1977 figures, ecosystem goods and services on a global scale are estimated to contribute 1.8 times more than the total global GNP. Nature's services clearly need to be integrated into cost-benefit analyses of environmental modification.

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