When you step outside, whether heading for your car or for a walk around the block, you expect to be able to breathe the air. When planting flowers in the window box or tomatoes in the raised bed in your backyard, you expect those plants to grow, flower, and produce seeds or fruit. When perusing the grocery shelves, you expect to find fresh produce, and affordable fish and meat. When you turn on the tap, you expect to be able to drink the water.

Ecosystem services are the processes through which natural ecosystems, and the plants, animals and microbes that live in those environments, sustain human life. Ecosystem services produce goods, timber, and fibers, medicines and fuels. Ecosystem services even conduct life-support activities, like filtering water and recycling all kinds of wastes. The natural services that for millennia have purified the water and air, supported the growth and reproduction of food plants, controlled pests, and even moderated the weather and its impacts are declining rapidly. Land clearing for agriculture, industry and mining, and development is affecting ecosystems worldwide. As habitats become fragmented, with only pockets left here and there, the services those natural systems provide become less effective.

Tom Lovejoy, Chief Biodiversity Advisor, The World Bank, says other natural services, like waste decomposition and flood control, are often overlooked. Technology may duplicate these services temporarily, but it's doubtful that technological advances will be able to continually compensate for the large-scale loss of natural services. Although it is difficult to put a price tag on a wetland, forest, or river, the "price" for failing to protect or nurture these natural services could be daunting. As we populate the planet, nature's services will become even more essential to humans and worthy of protection from even those who never leave the cities.

Wetlands: Water Purification System and Natural Flood Control

Most wetlands are linked intricately with our groundwater and surface water supplies. By the end of the 20th century, the United States had lost about 30 percent of its historic wetlands to draining, development, and agriculture. Over 85 percent of the inland surface water was controlled artificially and more than half the nation's fish populations were suffering from the effects of water pollution and high temperatures. Yet, wetlands continue to provide crucial ecological services, including filtering and conserving water, flood control, and shelter and food for fish and wildlife. Wetlands also help maintain cycles essential for life on earth, such as the carbon, methane, nitrogen, and sulfur cycles. Resource managers now realize that preservation and restoration of wetlands and natural waterways may be a more cost effective means of maintaining drinking water quality than expensive water treatment technologies.

Catskill Mountains - New York

Forests: Our Carbon Reserves

Natural services provided by forests go beyond shade, timber, and wildlife habitat. The vast tracts of deciduous and evergreen trees that cover more than 25 percent of the ice-free land on the planet help stabilize landscapes by protecting soils and retaining moisture. Although forests today cover only about half what they did historically, they remain major sites for carbon storage, are important for nutrient cycling, and help moderate local and regional climate through rainfall. Carbon-storing forests may even moderate global warming.

Boreal, tropical and temperate forests store 1,200 gigatons (billion tons) of carbon in their plants and soils. Compare that with the 750 gigatons stored in the earth's atmosphere. Even the urban forests of Chicago, with their 50.8 million trees, are estimated to store approximately 155,000 tons of carbon per year. U.S. Department of Agriculture scientists calculate that converting the 22 million acres of marginal cropland and pasture in the southern United States to forest would increase carbon storage in the region by 32 million tons per year. This could offset 3 percent of the country's annual carbon dioxide emissions. When forests are burned, carbon is released to the atmosphere. Researchers estimate that the yearly worldwide releases of atmospheric carbon from the burning of forests are increasing even more rapidly than the amount of atmospheric carbon released from the burning of fossil fuels.

We lose a lot more than carbon storage when we clearcut forests. Huge amounts of soil are lost when forests are cleared and erosion escalates. In Nepal, where trees are needed to stabilize steep slopes, between 30 to 75 tons of soil wash from each hectare of cleared land each year.

Nepal may contribute as much as 240 million cubic meters of soil each year to neighboring India's lowlands and waterways. In Africa, the deforestation of Ethiopia's forests from about 10 percent of land cover to only 3 percent has resulted in topsoil flowing from the country's high lands into the Blue Nile River. There, it silts up the Roseires Dam, hundreds of miles downriver in Sudan.

Forests also help regulate the water cycle when tree roots soak up rainfall; stems, trunks and roots slow runoff; and tree leaves release water back into the atmosphere. In addition, plant and animal biodiversity depends on intact, mature forests. In some cases, even human health may rely on that biodiversity. Many medicines have been isolated from plant compounds. Deforestation can contribute to a resurgence or redistribution of infectious disease, when the ecosystem processes that allow natural pest control is disturbed. In South America, insecticide-resistance, declining investments in public health programs, and forest clearing have contributed to a resurgence in malaria. Malaria-carrying mosquitoes are normally consumed by a wide variety of reptiles, birds, bats, and fish. Forest clearing removes habitat for these creatures, but clears the way for standing water where mosquitoes can breed freely.

Valuing Nature: What Would You Pay?

How much would you pay to save a local wetland or a tract of tropical rain forest? How much would your neighbor pay? You and your neighbor may not agree about what's important in that wetland or forest. It's not easy to put a price tag on a wetland and every wetland probably has a different value. It's important, however, to understand the value of a natural resource if it's to be preserved, continue functioning and effectively providing ecological services.

How do economists and environmental scientists calculate the value of the products and services provided by a natural resource? Think about the services provided by a large freshwater or saltwater wetland, perhaps one near you. Many types of fish spawn in wetlands and the young fish spend the beginning of their lives there. The annual worldwide fish catch is about 100 million tons and is worth $50-100 billion. That wetland may help contribute to this very lucrative commodity. What dollar value would you put on your local wetland's contribution to the global fish catch? The fish from freshwater sportfishing in the United States alone may be worth as much as $16 billion. Another $46 billion is generated employing people associated with that sportfishing industry. So, in addition to providing a nursery area for the fish you eat, a local wetland may indirectly employ someone in your community. But that isn't all a wetland provides. Flood control; water treatment and purification; nutrient cycling; wildlife habitat for hunting, viewing and photography; or other recreational opportunities, like boating and hiking, are on the short list of wetland amenities and services.

There are basically three categories of services and benefits, with some easier to price than others. Products, like fish or timber, are fairly easy to quantify, compared with services like nutrient cycling or water purification. Even harder to grasp in terms of economic value are the recreational, aesthetic and spiritual benefits humans gain from the natural world.

A study by the U.S. Army Corps of Engineers reveals a wide variety of methods for valuing wetlands, as well as vastly differing values. With so many methods, it becomes difficult to compare among studies. As you can imagine, these wide-ranging numbers make it hard for decisionmakers to apply a value to their local wetland. Nationwide, product values from fish, shrimp, oysters, and furs ranged from $.30/acre to $37.46/acre. Based on the price that public agencies paid for wetland preservation, the value of wetlands preserved for wildlife was estimated at $1200/acre, and high-quality wetland open space was valued at $5000/acre. A cost analysis of a federal wetland reserve program, which pays to convert cropland back to wetland, revealed easement payments of $105-$639/acre. Money spent on restoration that aims to improve ecosystem functioning was lower, from $89-$139/acre. Contingent valuation, where people are surveyed on their willingness to pay, revealed wetland users in coastal Louisiana were willing to pay $1,911 per year for use of the regional wetland. On the other hand, local residents living near a wetland in Kentucky were willing to pay only $6.31-$12.67 per household to preserve the wetland. A survey of hunters along the Pacific Flyway indicated they valued each duck taken at $3.29 and each pothole, where ducks live, was worth $8.88.

The following brief descriptions of several methods of valuing nature offer just a glimpse of these complicated calculations. More detailed explanations can be found at a website supported by the U.S. Department of Agriculture, Natural Resources Conservation Service (USDA, NRCS) and the National Oceanic and Atmospheric Administration (NOAA) or check our list of external links in the sidebar.

Direct, consumptive use values apply to products from natural ecosystems that are harvested and sold commercially, such as fish or lumber. Direct, nonconsumptive use values also are fairly easy to understand, but a bit harder to calculate. The benefits of bird watching, hiking and sightseeing can be calculated, based on how much it costs to travel to the accommodating habitats. For example, an Alaskan wilderness area directly benefits the residents and tourists who enjoy hiking and photography, although they leave with no products to sell. The local economy also benefits, as people dine in restaurants, stay in hotels, purchase equipment and souvenirs, and fuel their cars. Indirect value can also be assigned to that Alaskan wilderness area if other people enjoy watching a television show about the area and its wildlife.

The contingency method is useful when it's difficult to assign figures, because it surveys people on their "willingness to pay" for specified resources or ecosystem functions. Pennsylvania residents, for example, may be willing to pay a few cents per acre per year in taxes or private contributions to a nonprofit organization to help preserve that Alaskan wilderness area. "Willingness to pay" is subjective, however, with results depending on the concerns of the people surveyed, their proximity to the ecological service, their understanding of that service, and their personal ethics. Placing a price tag on non-use values is even more difficult. Many people say they are willing to pay for the possibility of visiting a habitat, the sheer existence of a resource, or to ensure the resource's existence for future generations. The Alaskan wilderness may be worth funding for people who consider wild open spaces, polar bears and migrating herds of caribou important, but will never travel to Alaska. Survey approaches are often the only way to ascertain non-use values, although many experts note that surveys can provide questionable results. Still, researchers and managers view the results as at least a gauge for valuing a natural resource.

Replacement costs, like calculating the cost of preserving land in the New York City watershed versus building a filtration plant, make easy comparisons, but only tell part of the story. Avoided costs are estimates of how much money would be spent if services had to be purchased. The value of natural pest control, pollination , flood control, soil fertilization, and water filtration are hard to calculate, because actual expenditures are avoided if the natural ecological services are intact and functioning properly. As a result, the risk and degree of a malfunctioning natural service and the projected cost of a technological fix must be estimated. The Hedonic property value method uses the prices of residential property to reveal the value of local environmental attributes. This method is limited to environmental services that are located near residential areas. Property values tend to increase if they're located near a lake or urban water amenity, or if the water quality of streams and lakes improves locally. Homeowners appear to place a value on at least the aesthetics of a wetland, although some homeowners also probably appreciate the flood control and water quality benefits of wetlands.

The traditional valuation techniques described above attempt to assign value to nature and its services. Jim Salzman, a professor at Washington College of Law, American University, notes that although these methods provide a common currency to measure nature's worth, they fail to capture the true value of ecosystems services. In addition, many of these valuation techniques also are expensive to calculate. They may require extensive survey development, questionnaire distribution, and follow-up. Much research must be done to calculate all of the variables associated with natural resource use, risk assessment, and projections of technological solutions. Indicator-based valuation tools can be less expensive and may require less time to develop and apply. These tools depend on ranking or prioritizing expected benefits of investments in the environment. The Environmental Protection Agency (EPA) estimates that, in 1997, the U.S. spent $210 billion complying with federal environmental regulations. Although this figure is subject to discussion and doesn't include state and local funding for restoration and conservation, it's apparent that substantial amounts of public money are spent to protect our natural services. Resource managers can use indicator-based valuation tools to decide where to most efficiently spend environmental protection dollars and where restoration might be most effective.

How Much is Biodiversity Worth?

The value of biodiversity is a good example of just how difficult placing a price tag on ecological services can be. Many environmentalists and experts use "biodiversity prospecting" as a significant reason for saving the world's rain forests. Tropical rain forests harbor the greatest biological diversity of species and ecosystems. Diversity of species, in turn, houses an immense variety of genes. Since 25 percent of prescription medicines contain active ingredients derived from plants, it's likely that the diversity of plants in a tropical rain forest will continue to offer new cures. As the use of biotechnology escalates, genes to improve agricultural, industrial, and pharmaceutical products will continue to be harvested from plants and animals. It seems reasonable to think biodiversity should carry a hefty price tag. But, Resources for the Future researcher R. David Simpson considers the contribution of biodiversity on the economic margin. Although there is no substitute for biodiversity as a whole, nature tends to create redundancy, so the benefits from saving an individual species or local habitat may be small. In the end, from an economic viewpoint, pharmaceutical companies show little willingness to pay to preserve tropical rain forests worldwide.

Simpson points out, however, that biodiversity is important for a number of commercial, ecological, aesthetic, ethical, and even spiritual reasons. Biodiversity prospecting simply may not have the economic pull needed to justify fully funding rain forest conservation. In the future, conservationists will need to look for other angles to preserve tropical rain forests, such as payment for local water purification services or international transfers from concerned conservationists worldwide.

Forecasting the Future of Nature's Services

If current trends continue, humans could dramatically and irreparably alter the planet's remaining natural ecosystems within decades. To determine what should be saved or restored now, politicians and resource managers need to know how their actions (or failure to act) may affect the future. Although actually forecasting specifics is currently difficult, modeling the activities within small-scale geographic regions that provide a series of services is feasible. Forecasting can determine at what point an ecosystem's ability to provide services may break down. The Institute for Ecological Economics, at the University of Maryland, is trying to give decisionmakers an idea of how today's activities might affect the Patuxent River, which flows into Chesapeake Bay, tomorrow. By developing new software and tools, researchers hope to improve the predictive ability of models that integrate watershed ecosystems with their human occupants.

The precision of future forecasting is dependent on the data gathered today. New technologies are helping gather and analyze the vast amount of information necessary to understand nature's services. Computer models can simulate some ecological conditions and economic projections, but integrating long-term environmental scenarios with economic behaviors and consequences is still in the development stage. Ecosystem model development has been going on for decades. A watershed model, like the Patuxent Landscape Model (PLM), utilizes environmental data from a number of studies of the Patuxent River watershed in Maryland. This river drains into Chesapeake Bay. Currently, the PLM ecosystem model can simulate "what if" scenarios, but human behavior must be input, rather than modeled internally. The ability to integrate economic factors, such as transportation, land use changes or landowner behavior, is still under development.

Global changes, from climate warming and sea level rise, to shifts in land use and population growth, will affect the flow of ecosystem goods and services. Reliable forecasting of how these changes will alter the supply and flow of ecosystem benefits requires extensive taxonomic, ecologic, economic and sociologic understanding. Accurate forecasting models require, not only understanding how the ecosystem works, but also placing a value on its functions and products, as well as predicting how things might change over time. Long-term data and strategies for future monitoring of both the environment and the economy are needed to provide an index of change.

Probably the best-known example of forecasting based on computer modeling is the weather. Predictions of local weather conditions often are fairly accurate. Longer-term forecasts, for even the next week, are less accurate. And when it comes to predicting the next year's weather, the *Farmer's Almanac* is probably consulted as often as the National Weather Service. Scientists are not deterred, however, and forecasting tools that integrate societal aspects, like food production and health, are probably just on the horizon. A recently developed model that examines the effects of climate change on rice production offers detailed scenarios of how increased carbon dioxide levels and temperature could affect major rice-producing countries in Asia. Such forecasting could give governments and farmers time to adapt their planting dates, experiment with rice varieties, and research other cropping practices to accommodate long-term changes in weather and climate.

Forecasting human health epidemics, based on weather patterns, has the potential to give governments and public health workers up to a year to get ready for a predicted disease. Climatic forecasting for southern Africa, which is affected significantly by the Pacific's El Nino and La Nina events, could help predict droughts and floods. Droughts in Mozambique have been associated with cholera, dysentery and plague. In 1995, La Nina-caused flooding in Mozambique and South Africa spurred upsurges in malaria. Researchers at the Liverpool School of Tropical Medicine note that much of the environmental information needed to develop a weather and malaria model is already available. Satellite imagery, and meteorological and climate data can provide the rainfall, temperature and humidity information most critical to predicting malaria epidemics. Such early warning systems will have to be extremely reliable. The price of a false prediction, in terms of both resources and credibility, would be substantial. On the other hand, reliable malaria forecasting warning systems could give public health workers time to budget and order drugs and insecticides, as well as launch a public health education campaign.

Forecasting the future is mostly still in the future. But, the data-gathering and technology development conducted today will help create reliable models for future forecasting.

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