POLICY FORUM

The Value of Nature and the Nature of Value

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The world's ecosystems are capital assets. If properly managed, they yield a flow of vital services, including the production of goods (such as seafood and timber), life support processes (such as pollination and water purification), and life-fulfilling conditions (such as beauty and serenity). Moreover, ecosystems have value in terms of the conservation of options (such as genetic diversity for future use) (*1*). Unfortunately, relative to other forms of capital, ecosystems are poorly understood, scarcely monitored, and (in many cases) undergoing rapid degradation and depletion. Often the importance of ecosystem services is widely appreciated only upon their loss.

This is beginning to change, most notably in Australia and Costa Rica. An Australian firm called Earth Sanctuaries, Ltd. was listed on the Australian Stock Exchange in May, making it the world's first conservation company to go public. The U.S.$25-million firm buys up land (90,000ha so far) and restores native vegetation and wildlife, earning income from tourism, consulting, and wildlife sales (*2*). The firm lobbied for and won a change in accounting law so as to include its rare native animals as assets. Meanwhile, the Sydney Futures Exchange is positioning itself to be a global leader in the trading of ecosystem services, from carbon sequestration (the withholding of carbon, a greenhouse gas constituent, from the atmosphere by plants and soils) to 'new environmental products,' such as credits for clean water and biodiversity. The CEO of State Forests of New South Wales is promoting a vision of foresters marketing a wide array of ecosystem services, with timber as a 'by-product' (3). The Commonwealth Scientific and Industrial Research Organization and The Myer Foundation have just launched the most advanced assessment of ecosystem assets in the world (*4*).

Since 1997, the government of Costa Rica has been paying landowners for several ecosystem services: carbon sequestration and protection of watersheds, biodiversity, and scenic beauty. The payments, about U.S.$50/ha-yr, are financed in part by a tax on fossil fuels and are resulting in significant forest conservation and restoration (5). Costa Rica has also sold carbon sequestration credits to several European nations. These and other promising government initiatives are supported by scientific expertise and growing industry participation (*6*).

Worldwide, ecosystems are being protected or restored to control floods, filter water, enhance soil fertility, stabilize climate, offer human enjoyment, and even to recycle orange peels (*7*). Such efforts are being rewarded with innovative financial mechanisms, whose scope and variety are expected to grow (see table).

Commodity	Share of farm business (%)
Wheat	40
Wool	15
Water filtration	15
Timber	10
Carbon sequestration	7.5
Salinity control	7.5
Biodiversity	5

A hypothetical Australian farm business in 20 years (*8*). In this model, traditional agricultural commodities account for 55% of revenues, as opposed to 100% today. Other income derives from a mature market for ecosystem goods and services.

These developments all involve putting a price tag on nature, an act seen by many as risky at best (*9*). To be sure, individuals and societies already assess the value of nature implicitly in their collective decision-making, too often treating ecosystem services as 'free.' Until recently, this was generally safe to do: relatively speaking, ecosystem capital was abundant and the impacts of economic activity were minimal. Ecosystem capital is becoming ever scarcer (*10*), however, so that it is now critical to understand both how to value ecosystems and the limitations of such valuations.

Ecological Basis for Valuation

To establish sound policy, the 'production functions' describing how ecosystems generate services need to be characterized, and the interactions among these functions quantified. To begin, a cataloguing of the sources and consumers of ecosystem services is needed. For any given location, this would document service flows occurring locally (such as pest control, serenity), across regions (such as timber export and flood control), and globally (such as climate stabilization).

The production functions would also reveal critical points and interdependencies in the supply of services, and the time scales over which services are amenable to repair. Yet these are poorly known now and are likely to remain elusive. Ecosystems typically respond nonlinearly to perturbation. For example, gradual increases in salinity for decades went unnoticed by farmers in Australia, but have now reached crisis levels. Replanting native vegetation reduces soil salinity (a benefit) but also reduces river flow (a cost). Furthermore, ecosystems are idiosyncratic; what holds true in one region may not apply well elsewhere. Soil salinity appears controllable with ecosystem approaches in eastern parts of Australia, for example, but in Western Australia the threshold is higher and there is little hope for reversal without enormous investment. Putting theory into practice will therefore require locally based information.

Principles of Valuation

There are three fundamental steps of decision-making. In this context, all require integration of ecological and economic understanding. The first step, identification of possible alternatives, is probably the most important but also the most underrated. Often the identification of alternatives is guided by narrow conventions: if a city is expanding its water treatment system, engineers may evaluate different physical treatment plants, ignoring ecosystem approaches (watershed or wetland management).

The second step requires that all impacts be identified and measured for each alternative: everything from immediate needs for labor, capital, and other inputs to long-term biophysical and social impacts. Rarely does sufficient knowledge exist to make precise estimates, but it is important to try to quantify uncertainties and the risks of proceeding.

The final step, valuation, translates the consequences of maintaining the status quo and opting for each alternative into comparable units of impact on human well-being, now and in the future. These

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impacts are defined in terms of the resources people would be willing to forego to get the goods, services, or other outcomes associated with a particular alternative. The common measuring unit is typically monetary (*11*).

Embedded in this process are several general principles: (i) Public policy decisions involve making incremental, not revolutionary, changes to the status quo. Calculating the total value of ecosystem services, by contrast, is not very helpful. (ii) In a democratic society, values used in social decision-making ought to be derived from those held by its individual citizens, and not be imposed by the state. (iii) We should infer peoples' values as they are revealed by actual decisions whenever possible.

Scope and Limitations of Valuation

In practice, valuation of ecosystem assets involves some of the oldest problems in economics: revealing and aggregating preferences, and addressing uncertainty. There are drawbacks associated with most ways of inferring value. Market prices often do not reflect the full social costs of production (*12*); moreover, most services are not presently traded on markets. Methods of indirect revealed preference (for example, valuing clean air by comparing land rents in clean vs. polluted areas) are not relevant to setting a value on the existence of certain assets (such as the satisfaction derived from contemplating the existence of a tropical rainforest). Approaches based on avoidance of costs (for example, valuing natural water purification at the cost of its technological alternative, a filtration plant for instance) provide only partial, lower bound indications of value, especially for services without adequate substitute (such as global climate regulation). Contingent valuation surveys (that try to elicit how individuals value hypothetical incremental changes) are improving but still notoriously unreliable, especially when applied to issues with which the public is unfamiliar.

Reliance on individual preferences to construct social values, although defensible on ethical grounds, has serious pitfalls. Preferences depend on institutional context – how much individuals know about the environment, for instance (*13*). The outcome of economic valuation is in this respect not more informed than the people whose values are being assessed.

Even if we were able to measure individual values accurately, we still must determine how to aggregate these into a social value. Ultimately the weights used involve a value judgement; there is no 'correct' answer. Treating all people equally is appealing in principle but by no means universally accepted.

Measurement of incremental values works best when the increments are small so that a change in one service will have minimal feedbacks through the rest of the system. Values of various increments can then be estimated separately and simply added. Unfortunately, this condition is difficult to meet for ecosystem services, where the underlying systems tend to be highly interdependent and seemingly small changes in one place cause large impacts on the overall system (*14*). The level of uncertainty in our understanding of ecological processes suggests that it would be prudent to avoid courses of action that involve possibly dramatic and irreversible consequences and, instead, to wait for better information.

Another key problem is the relative weight put on current versus future costs and benefits. The choice of 'discount rate' is very important where a long time frame is involved; sufficiently high discounting can be used to justify policies that exploit resources now at the expense of substantial environmental costs later. Individuals tend to discount their own futures, whereas 'equal treatment' would have future generations treated the same as current ones. Some social discounting is consistent with such equity if future generations will be better off than current ones, a situation that may not continue to prevail (*15*).

The State of the Art

Valuation is a way of organizing information to help guide decisions, but not a solution or end in itself. It is one tool in the much larger politic of decision-making. Wielded together with financial instruments and institutional arrangements that allow individuals to capture the value of ecosystem assets, however, the process of valuation can lead to profoundly favorable effects (*16*).

The rapid institutional change presently underway is inspiring for several reasons. It shows that the most important decisions to get right are those where benefits greatly outweigh costs or vice versa, and in such cases complete accuracy is unnecessary. For example, by constructing crude lower bound estimates for the value of natural water purification services, municipalities worldwide are determining that preserving or restoring natural services is often preferable to constructing a water filtration plant (*17*). The new initiatives also account for the interdependence of services; in Australia and Costa Rica, for instance, multiple services are being bundled to achieve the desired relative increases in supply via changes in land use. With luck, the protection of well-known or highly valued services (such as salinity control and carbon sequestration) will suffice, for now, in preserving those that are poorly known (such as pollination) (*18*). Finally, the initiatives are generating demand for, and spurring the development of, integrated ecological-economic-social approaches to managing ecosystem assets, and the potential for such approaches is tremendous.

References

1. G. C. Daily, Ed. *Nature's Services* (Island Press, Washington, DC, 1997); G. C. Daily, *Conserv. Ecol.* http://www.consecol.org/vol3/iss2/art14 (1999).
2. *Earth Sanctuaries, Ltd. Prospectus 2000*, Stirling, South Australia. http://ww.esl.com.au.
3. L. Hosking, R. Smith, and D. Brand, Presentations at "Forests in the Green Economy," a conference cosponsored by the Sydney Futures Exchange, Forests Trends, and State forests of NSW, 10-12 April 2000, Sydney. http://www.forest.nsw.gov.au
4. S. Cork and D. Shelton, in *Sustainable Environmental Solutions for Industry and Government*, Proc. 3rd Queensland Environmental Conference, Brisbane May 25-26, 2000 (in press); http://www.dwe.csiro.au/ecoservices/
5. R. Castro, F. Tattenbach, L. Gámez, N. Olson. 1998. *The Costa Rican Experience with Market Instruments to Mitigate Climate Change and Conserve Biodiversity*. Fundecor and MINAE, San José, Costa Rica.
6. R. Gámez Lobo, *De Biodiversidad, Gentes y Utopías* (INBio, Sto. Domingo, Costa Rica, 1999).
7. G. Heal, *Nature and the Marketplace* (Island Press, Washington, D.C., in press); M. Echavarria and L. Lochman. *Policy Mechanisms for Watershed Conservation*, (The Nature Conservancy, Arlington, VA, 1999).; D. Janzen, *Proc. Nat. Acad. Sci. U.S.A.* **96**, 5987 (1999).; W. Reid, in *Managing Human-Dominated Ecosystems* (Island Press, Washington D.C., in press); E. Masood and L Garwin, *Nature* **395**, 426 (1998).
8. C. Binning and R. Smith, Presentations in Ref (*3*).
9. D. Ludwig, *Ecosystems* **3,** 31 (2000); M. Gatto, and G. De Leo. *BioScience* **50**, 347 (2000).
10. P. Vitousek, H. Mooney, J. Lubchenco, J. Melillo. *Science* **277,** 494 (1997).
11. There is a good case for using multiple numeraires. S. Schneider, K. Kuntz-Duriseti, C. Azar. *Pacific Asia Journal of Energy* (in press).
12. R. Naylor *et al. Science* **282,** 883 (1998); R. Naylor *et al. Nature* **405** (in press).
13. R. Costanza, *Ecosystems* **3**, 4 (2000).
14. For example, small changes in the phosphate loading in a lake can cause it to flip from a clean state to one of high turbidity. Scheffer, M. *Ecology of Shallow Lakes*. (Chapman & Hall, London, 1998).
15. K. Arrow *et al.*, in *Climate Change* 1995, J. Bruce, H. Lee, E. Haites, Eds. (Intergovernmental Panel on Climate Change and Cambridge Univ. Press, 1996), pp. 125-144.
16. F. Berkes and C. Folke, Eds., *Linking Social and Ecological Systems* (C.U. Press, Cambridge, 1998); G. Heal, *Ecosystems* **3**, 24 (2000).
17. E.g., G. Chichilnisky and G. Heal. *Nature* **391**, 629 (1998); Nat. Research Council, *Watershed Management for Potable Water Supply* (National Academy Press, Washington, DC, 2000); (*7*).
18. See C. Kremen, J. Niles, M. Dalton, G. Daily *et al.*, *Science* **288**, 1828 (2000).

19. We benefitted from discussions with C. Binning, J. Eagle, M. Freeman, L. Gámez, and J.Salzman.