Ecosystem Services:
Dynamics, Modeling and Valuation to Facilitate Conservation

Project funded by the Gordon and Betty Moore Foundation

Project Overview

Various new social institutions are being developed to use information about the value of ecosystem services in order to better conserve them. For example, Costa Rica and other countries have systems of payments to individual landowners for the ecosystem services their land produces when maintained in a conserved, forested state.

What is needed now is a more sophisticated and transferable system to allow ecosystem managers to quickly understand the dynamics of ecosystem services in their area, how these are linked to human welfare, and how their function and value might change under various management scenarios. We also need better information on the dependence of various ecosystem services on the spatial pattern of land use and the scaling of information on local ecosystem services to watershed, national, and global scales.

Project Outcomes and Activities

This project integrates participatory modeling, data collection, valuation, and outreach that will take the study of ecosystem services to the next level and allow the results to be effectively used in a number of critical environmental management contexts. Ecosystem services are defined as those functions of ecosystems that support (directly or indirectly) human welfare (Costanza et al. 1997, Daily 1997). The three major outcomes of the program, and the activities proposed to achieve these outcomes, are summarized below.

Outcome 1. A suite of dynamic ecological economic computer models specifically aimed at integrating our understanding of ecosystem functioning, ecosystem services, and human well-being across a range of spatial scales.

Models and their supporting data bases will be produced using participatory, "mediated modeling" workshops, involving key ecosystem scientists, ecological economists, ecosystem managers, and students (c.f. Higgins et al. 1997, Costanza and Ruth 1998, van den Belt 2004). We will form task groups for each of the following major ecosystem types that occur in the Gordon and Betty Moore Foundation's (GBMF) environmental target areas (Andes/Amazon, Pacific Northwest, Marine): (1) Forests; (2) Grasslands; (3) Wetlands; (4) Lakes/Rivers; (5) Cropland; (6) Urban; (7) Open Ocean; (8) Coastal Ocean.

Each task group will be led and coordinated by a senior participant. The overall task will be coordinated by the project PI, Robert Costanza. Each task group will meet twice for 5 days each visit in Burlington, VT. All groups will meet at the same time, to allow coordination and interchange between the groups. The sessions will alternate between

individual task group meetings and plenary sessions to report back intermediate results. Between sessions, participants will work on model development, with some support funding from the project. We have extensive experience with this approach to collaborative science, synthesis, and modeling, having used it successfully for a number of projects, including several working groups at the National Center for Ecological Analysis and Synthesis (NCEAS) in Santa Barbara (see Farber et al. 2006 for results from the latest of these working groups). The resulting models (in combination with GIS data and web-based outreach facilities as described below) will allow a relatively sophisticated dynamic analysis of ecosystem services at any point on the globe.

The models will also be linked into spatial arrays allowing spatially explicit landscape models to be constructed (cf. Costanza et al. 2002, Costanza and Voinov 2003) from the watershed up to the global scale (Boumans et al. 2002). Two additional task groups will develop watershed scale models for parts of the Amazon and the Pacific Northwest, using the unit models developed by the ecosystem task groups. One additional task group will develop an integrated, spatially explicit, global scale model. We will build on our previous work with the GUMBO integrated global model (the only integrated global model currently available that deals explicitly with ecosystem services - Boumans et al. 2002), incorporating the results of the individual ecosystem task groups and producing a spatially explicit model capable of answering a range of questions about ecosystem service dynamics and value at the global scale. For example, this model would be able to address questions about the impacts of rapid climate change on ecosystem services.

The models will be linked with remote sensing data and a GIS data base, allowing the models to be parameterized and used for any location on the planet. As mentioned above, the spatial proximity of particular patches of an ecosystem relative to other systems is an important characteristic in determining its functioning and value. The proposed system would allow (for the first time) adequate consideration of this effect in ecosystem services modeling and valuation. The project will also tie in to the ongoing NSF funded LTER (Long Term Ecological Research) network and other sites rich in ecological data to help calibrate and test the models. Historical data will also be incorporated to set baseline conditions and help calibrate the models.

The resulting models (in combination with GIS data and web-based outreach facilities as described below) will allow a relatively sophisticated analysis of ecosystem service dynamics at any point on the globe. This will enable the concept of ecosystem services and their value to humanity to be effectively used in a number of decision contexts.

Outcome 2. Development and application of new valuation techniques adapted to the public goods nature of most ecosystem services and integrated with the modeling work.

Conventional economic valuation presumes that people have well-formed preferences and enough information about trade-offs that they can adequately judge their "willingness-to-pay." These assumptions do not hold for many ecosystem services.

Therefore, we must:

(1) inform people's preferences (for example by showing them the underlying dynamics of the ecosystems in question using the models developed in Outcome 1); (2) allow groups to discuss the issues and "construct" their preferences (again using the models developed in Outcome 1 to inform the discussions); or (3) use other techniques that do not rely on preferences to estimate the contribution to human welfare of ecosystem services (i.e. using the models developed in Outcome 1 to directly infer marginal contributions to welfare). In this project we will combine these three methods to develop new and more integrated methods to value ecosystem services.

Assessing the value of changes to ecosystem services involves two distinct steps: (1) assessing the biophysical changes in ecosystem services caused by policies or patterns of human use, and (2) assessing the impacts of these changes on human welfare. While much attention has been paid in the valuation literature to the second of these steps, it is clear that the first is equally important and often much more difficult. In this project we will:

- Integrate these two steps to achieve a meaningful and useful assessment of the value of ecosystem services by developing ecosystem service valuations that can be linked to the models outlined in Outcome 1.
- Model dependence of ecosystem service values on the spatial patterns of land use.

Both old and new valuation techniques will be necessary to accomplish this. In this project we will use established techniques as appropriate, but also further develop more novel techniques as needed. These new techniques include: production function approaches, conjoint analysis of model scenarios, and group valuation. These approaches are briefly described below.

Production function approaches. This approach recognizes that ecosystem services are important inputs to traditional economic production processes and also contribute directly to human welfare without ever passing through the market economy. This valuation method can be effectively linked to ecological models (of the type we will be developing) that provide estimates of the levels of services under various scenarios and links them to production and welfare functions built into the models. For example, forests provide water supply and flood protection services that can be valued in proportion to their marginal contributions to the model's production and welfare functions.

Conjoint analysis of model scenarios. Conjoint analysis has long been used by market researchers to understand how consumers trade off product attributes to make purchase choices. Developed by mathematical psychologists, the distinctive feature of conjoint analysis is that it permits the valuation of individual attributes based upon choices between scenarios with varying attribute levels. This is particularly relevant to ecosystem services valuations, since an ecosystem simultaneously provides a complex set of services, or attributes. Individuals may be unwilling or unable to establish independent valuations of each service, but can reveal implicit valuations through choices

among multi-attribute service scenarios. The unique feature of this project is the ability to directly link the conjoint analysis to model scenarios, which are more realistic descriptions of the trade-offs inherent in the systems.

Group valuation: Many of the services that need evaluation are public in nature; i.e., their benefits accrue to the public at large. And public policies toward ecosystem services involve entire communities making decisions. In this context, it may be particularly relevant that valuations be made in group decision contexts, rather on an independent, individual basis. In addition, there may be instances in which individuals have poorly formed, or erroneous knowledge of the importance of services, either to them or their community. Group valuation processes, that include discussion and feedback before final valuations are established, can be useful in informing valuation participants. The unique feature of this project is that it can use the integrated ecological economic models developed in Outcome 1 to help inform the group of the underlying structure and dynamics of the systems they are valuing. The project will use these new valuation techniques to value ecosystem services, and these new valuations will be integrated into the models and communicated via the methods described in Outcome 3.

Outcome 3. Delivery of the integrated models & results to a broad range of potential users.

To catylize the use of ecosystem service valuation, the models, data and other outputs must be effectively available to the public, stakeholders, decision-makers, nonprofits, educational institutions, businesses and government agencies. A small fraction of the project effort will be devoted to disseminating the project results in both conventional and non-conventional ways.

This component of the project will include:

- Publish reports on the project results in various academic and popular print media. For example, a synthesis of the project results will be submitted to Nature.
- Integrate the project results into problem-based atelier courses.
- Distribute the models, supporting data and an interactive valuation tool in a user-friendly, highly accessible format. The web-based ecosystem tool would integrate the modeling, database, GIS and new valuation methodologies into a new valuation and management tool. This would allow users to provide information on a specific ecosystem and calculate their dynamics and value. The models could also be used to demonstrate how these values change with changes in some variables or policies. This could be conducted in a spatial context that is site specific, regional, or global in scale. This tool would have great potential for improving current analysis and management that largely omits ecosystem services. A website will be created for the project and will provide access to:

    - Results of the modeling workshops
    - Spatial models (landscape/global) including the Pacific NW and Andes/Amazon
    - GIS, ecological and economic data used in the ecosystem and modeling analyses

- A database of ecosystem services which the Gund Institute has developed and will supplement with new data from the project
- Information on new valuation techniques
- An interactive valuation tool that will allow users to enter in GIS and ecosystem data and derive a range of ecosysetm service values based on the dynamic models
- Materials, concepts, references, slides and talking points that users can apply in developing their own effective ecosysetm service presentations
- Policy options that will allow users to consider different practical policy tools

References

Boumans, R., R. Costanza, J. Farley, M. A. Wilson, R. Portela, J. Rotmans, F. Villa, and M. Grasso. 2002. Modeling the Dynamics of the Integrated Earth System and the Value of Global Ecosystem Services Using the GUMBO Model. *Ecological Economics* 41: 529-560

Costanza, R. and A. Voinov (eds). 2003. Landscape Simulation Modeling: A Spatially Explicit, Dynamic Approach. Springer, New York. 330 pp

Costanza, R., A. Voinov, R. Boumans, T. Maxwell, F. Villa, L. Wainger, and H. Voinov. 2002. Integrated ecological economic modeling of the Patuxent River watershed, Maryland. *Ecological Monographs* 72:203-231.

Costanza, R. and M. Ruth. 1998. Using dynamic modeling to scope environmental problems and build consensus. *Environmental Management* 22:183-195.

Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R. V., Paruelo, J., Raskin, R. G., Sutton, P., & Belt, M. van den (1997). The Value of the World's Ecosystem Services and Natural Capital. *Nature*, 387, 253-260.

Daily, G.C. (1997). Nature's Services: Societal Dependence on Natural Ecosystems. Washington D.C.: Island Press.

Farber, S., R. Costanza, D. L. Childers, J. Erickson, K. Gross, M. Grove, C. S. Hopkinson, J. Kahn, S. Pincetl, A. Troy, P. Warren, and M. Wilson. 2006 Linking Ecology and Economics for Ecosystem Management: A Services-Based Approach with Illustrations from LTER Sites. *BioScience* 56:117-129.

Higgins, S. I., J. K. Turpie, R. Costanza, R. M. Cowling, D. C. le Maitre, C. Marais, and G. Midgley. 1997. An ecological economic simulation model of mountain fynbos ecosystems: dynamics, valuation, and management. *Ecological Economics* 22:155-169.

Van den Belt, M. 2004. Mediated modeling: a systems dynamics approach to environmental consensus building. Island Press, Washington, DC