GETTING A HANDLE ON ECOSYSTEM SERVICES

Ecosystems provide society with valuable services such as food, clean water, fresh air and energy. They protect us from floods, droughts and disease, and give us healthy soils and cycle nutrients. The idea of ecosystem services is being adopted in some areas. But, says Naomi Lubick, is there an effective way of valuing these services?

Society needs a much clearer idea of the services ecosystems provide for us. Land-use change is perhaps the biggest human impact of all on terrestrial ecosystems. For this reason global environmental-change researchers interested in land use are no longer limiting their view to ecosystems alone. They are adding human systems into the mix, and calling it "land systems" – the coupled socio-environmental and terrestrial system that includes land use, land cover and ecosystems.

The results of this line of thinking are already attracting attention. In 2009, a collection of six related papers published in *Proceedings of the National Academy of Sciences* (*PNAS*) was awarded the Sustainability Science Award of the Ecological Society of America. The papers, co-authored by researchers associated with an IGBP joint project, the Global Land Programme (GLP), dealt with wide-ranging challenges from urban sprawl in the United States to improving the quality of animal feedstock in the French Alps and the vagaries of drought and livestock markets on land management in Australia. It turns out that some of the key factors governing ecosystem functioning were both unexpected and surprising.

According to Professor B L Turner II, the editor of the *PNAS* collection, the papers show "where land-change science is going". The environmental geographer, who recently moved to Arizona State University from Clark University, says the authors were "trying to demonstrate… that there's a series of large complex problems, integrated problems, in which the whole cannot be understood without the coupled pieces". But can one method assess the value of an ecosystem and predict how land-use change will devalue ecosystem services?

First step

The simple answer is no. Depending where on the planet you live, human land use and ecosystem change might lead to the intru-

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sion of seawater into groundwater on coastal agricultural lands as farmers pump more fresh water during droughts; severe and rapid soil erosion in clear-cut forests, whether in Brazil or Indonesia, with impacts on carbon dioxide in the atmosphere; loss of endemic species in fields turned to home lots in suburban United States; or forced migration because of rising sea levels.

All of these scenarios come back to ecosystem services and the perceived value of a landscape to humans and how they use it.

The growing importance of ecosystems services over the past decade was recognised by the Millennium Ecosystem Assessment (MEA) published in 2005, which played a seminal role in shifting attitudes toward modelling human impacts and land uses, says Alexander de Sherbinin, a senior research associate at CIESIN (Center for International Earth Science Information Network), at the Earth Institute at Columbia University in New York City. De Sherbinin says, "MEA was very important: its framework and approach to understanding ecosystems changed the perspective from 'we need to protect biodiversity' to 'look, there are all these services provided'."

Because of this sea change in thinking about ecosystems, de Sherbinin continues, "now everybody talks about ecosystems services" when addressing sustainability issues – no longer "protecting just flora and fauna".

Modelling the world

Valuing ecosystem services was a profound development, says Turner, but economists still struggle to put dollar values to services like wetlands water purification, the aesthetic beauty of a forest or carbon dioxide storage in peat to prevent climate change (though carbon is now easier to evaluate because of market trading). And while political ecology has come at these issues from the human side – considering ownership, politics and impacts on humans and by humans – land-change science adds humans to the landscape as another integral component, along with plants, animals, soil, water and more, Turner emphasises.

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Turner adds that it's not as simple as demonstrating that humans suffer once a service is degraded, "There's no correlation, at least in the short run, between the material well-being of society and deterioration of [ecosystem] services." And that means that land-use science must show the connections between an ecosystem and how it affects human outcomes.

"You want to ask the question: what are trade-offs between ecosystem services? That means you understand [that system]", Turner says. "The human element is so strong, it is already taking away value and structure of the system." He lists some of the myriad questions that need to be asked: What are the systems out there? How are they coupled? What does that mean for human consumption, social equality and other human issues?

Thinking small

In the French Alps, for example, where alpine pastures feed cattle over the summer, researchers find that the presence of certain plants with tender leaves and high nitrogen content make all the difference in weight increase for the livestock. Professor Sandra Díaz of the Universidad Nacional de Córdoba (Argentina) and her colleagues created a two-stage decision tree that let them test each plant species' traits weighed against variables such as soil type, climate, and other non-biological conditions, all in the service of providing feed for grazing, soil fertility, or other community-valued endpoints.

In the first steps, researchers test the effects on ecosystem properties of core drivers individually: non-biological factors like rain and elevation, traits that are distributed across the community and then averaged to get a weighted value, and particular species and their impacts on an ecosystem. The second stage takes the combined possible effects of these factors that are statistically significant and tests them together, looking for the best predictive model of what might happen, when, say, one species is removed from a foodweb.

"Using our method, we realised the most important factor in weight increase in livestock is the presence of certain plants with tender leaves and high nitrogen content," says Díaz, and to keep that particular service, a land manager in this alpine setting would have to make sure to keep plant species that fit the bill. But a landscape could be poised to give very different services – from birdwatching to carbon sequestration to water retention. Depending on the services people care about, the team's system could help determine which components of the ecosystem most strongly influence those services. Díaz and her colleagues are now working to apply the modelling tree to local ecosystems in Argentina, and she has heard that other researchers are interested in using it as far afield as Australia.

"Why is this an improvement?" Díaz asks. "Before, people were simply studying statistical relationships… between services and diversity with just a number of species. It didn't tell you much as to how [an ecosystem] was functioning or what you could do to preserve it."

She emphasises that the team's model is "completely useless if you don't know a minimum number of things about a system", from the influence of soil texture to the range and variety of species in a place. Modelling of all these components over different timescales can show changes in time or single snapshots, depending on the data available.

While the model (which received the Cozzarelli Prize in 2007 for "exceptional contributions to the scientific disciplines represented by the National Academy of Sciences", Class VI Applied Biological, Agricultural, and Environmental Sciences) was purely biological, Díaz says she is working on "trying to link it up with ecosystem services as defined not by scientists, but by the local stakeholders. The concept of ecosystem services is so rich, and so socially dependent, that we need to get into the details: different habitats, different peoples… it's really ecosystem specific."

"There are all these analytical issues we still haven't been able to solve," Turner notes, but Díaz and her colleagues' contribution is "one step on the biophysical side. The next step is to translate to human outcomes."

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Changing climate

One of the biggest challenges facing humans and their land-use choices is shifts in global climate, which are already intrinsically difficult to model. And this is where some researchers think these inclusive land-use models that integrate humans could be quite useful. "Climate change is sort of a matrix that sits over the whole thing," says Steve Carpenter of the University of Wisconsin-Madison, who has co-authored research with Díaz. "When we think about configuring landscapes, we have to think about a very long time horizon of directionally changing climate."

Some landscapes will be very vulnerable to climate change, while others will not. For example, in a region where evapotranspiration will increase, water stress will be greater for both people and other living organisms there. One solution would be to manage a landscape so that it absorbs water, "or create a water-bank in that area", Carpenter says.

Climate change also leads to a second big issue: the allocation of land to mitigate climate effects. "Carbon storage is a prime example there… but under many scenarios, future land storage [of carbon] is going to diminish," Carpenter points out, as forests disappear and soils degrade, for example.

"Nowadays, it's really, really hard to talk about climate change and land-use change separately," comments Díaz. "Both influence each other, [with] changes in climate triggered by land use, and the other way around." Ideally, she continues, her team's local model might lead to insights into which plants will have the right climate tolerance for a region. And if a key species disappears, "then you can anticipate [that and] start looking for another legume as close as possible to the one before with wider climate tolerance."

But Díaz emphasises that her team's model works at the local scale, from patches to landscapes, and it's difficult to scale up. Climate models, on the other hand, do best at large scales, and regional climate assessments are less certain.

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Management troubles

"There's a notion out there that we'll be able to manage huge tracts of land for carbon, for water… for all sorts of things. My own take is more sceptical," comments de Sherbinin. He ticks off classic examples that have worked, such as the Catskills watershed that supplies water for New York City and China's afforestation efforts to prevent future devastating floods on the Yangtze River.

De Sherbinin also mentions California's steps to require developers to consider carbon sequestration before building, as buildings replace forest, peat or other ecosystems that lock away greenhouse gases. "It's a reality – they basically have to address this now, so it's not entirely pie-in-the-sky that these issues won't come forward," he says. But while "we have the tools… land isn't managed that way generally."

Díaz says that the emerging land-system discipline, sometimes referred to as "coupled human-environmental systems" or "coupled social ecological systems", is interdisciplinary, but researchers need to remember: there is "no distinction between the human and the environment, nor should there be". Díaz concludes: "Part of our failure to manage the land in a better way so far is a lack of realisation that we have to approach the system interdisciplinarily".

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Everybody now talks about ecosystem services when addressing sustainability issues.

MORE INFORMATION

The Ecological Society of America granted the 2009 Sustainability Science Award to a special feature on land-change science, 'Evolution of urban sprawl', which appeared in the journal *Proceedings of the National Academy of Sciences,* 26 December 2007.

Turner B L II, Lambin E F, Reenberg A. Land Change Science Special Feature: The emergence of land change science for global environmental change and sustainability. *PNAS 2007 104:20666-20671; published online before print 19 December 2007, doi:10.1073/pnas.0704119104*

B.L. Turner II is on the scientific steering committee of the Global Land Project, co-sponsored by IGBP and the International Human Dimensions Programme.