

Taking the Pulse of Earth's Life-Support Systems

A massive effort to document the state of ecosystems—and their ability to provide food, comfort, and other services—lays out some grand challenges, but no easy answers

The plan was nothing if not ambitious: assess the state of ecosystems across the entire planet, from peat bogs to coral reefs. Rather than solely chart pristine habitats and count species, as many surveys have done, the \$20 million Millennium Ecosystem Assessment (MA) put people and their needs front and center. At its core was the question: How well can ecosystems continue to provide the so-called services that people depend on but so often take for granted? These include not just the food and timber already traded on international markets but also assets that are harder to measure in dollar values, such as flood protection and resistance to new infectious diseases.

In another novel approach, the assessment simultaneously examined this issue across a huge range of scales from urban parks to global nutrient cycles. The goal in each case, says director Walter Reid, was to offer policymakers a range of options that might help ecosystems recover or improve their role in providing for human well-being. The participants tried to make clear the tradeoffs involved in managing land; some methods of boosting crop yield, for example, exact a long-term price of degraded soils and incur downstream consequences such as fisheries stunted by fertilizer runoff. What's good for people in one region may cause harm in another place or time.

The project didn't aim to generate new data but to analyze and synthesize published, peer-reviewed research; even that was easier said than done. Some 1360 scientists from 95 countries spent countless hours poring over the literature, hashing out disagreements at meetings, and writing the first volumes of reports that will ultimately number some 3000 pages. In the process, they had to nail down nebulous terms such as biodiversity and cultural services and deal with the headaches of data gaps. "Doing a global assessment of

ecosystem services poses huge problems; it really pushes the envelope," says an apparently indefatigable Reid.

There's broad agreement that the envelope has been filled with a valuable status report, the first overview of which was released this week. "It is a magnificent achievement," comments Stuart Pimm, an ecologist at Duke University in Durham, North Carolina, who



Fragile. Drylands are some of the most delicate ecosystems in the world and face increasing demands, which could threaten efforts to fight poverty.

reviewed parts of the effort. "There will be a 'Wow!' when people see this." But will it actually influence policy? Most say it's much too early to tell. Participants argue that the bottom-line focus boosts the odds for action. "This will make it much more relevant for policymakers," says Peter Bridgewater, secretary general of the Ramsar Convention on Wetlands, who was on the MA's board. "It's not just scientific dancing on the head of the pin."

Widespread degradation

The MA's first report,* a summary of the major technical reports to follow, identifies three main problems with how humans are managing ecosystems. Topping the list is widespread abuse and overexploitation of resources. Although some ecosystems have yielded more and more goods—principally fish, livestock, and crops—their integrity, and the productivity of many more, has been compromised. Of the 24 kinds of services described by the MA, 60% are being degraded, the report found. "We're undermining our ecological capital all around the

Ecosystem Services

- Provisioning**, including food, water, fuel, and fiber.
- Regulating**, such as the prevention of soil erosion and flooding.
- Cultural**, including recreation, spiritual values, and a "sense of place."
- Basic support**, including soil formation, nutrient cycling, and oxygen from photosynthesis.

world," says Robert Watson, chief scientist of the World Bank and a lead author.

Second, and a bit of a surprise to some, the degradation is probably hiking the risk of sudden, drastic changes in ecosystems, such as the collapse of fisheries or the emergence of new diseases from fragmented forests (see box, p. 43). "When we started, that was not something that scientists might have listed as a top conclusion," Reid says.

Finally, the pressure on ecosystems is disproportionately harming the poor. That's particularly true in the drylands of sub-Saharan Africa, central Asia, and Latin America, where a third of the world's population tries to make do with 8% of its fresh water. The report argues that healthy ecosystems are key to alleviating poverty and meeting other objectives in the U.N.'s Millennium Development Goals. "The rationale is that only by protecting and restoring the ecological function will you be able to adequately address hunger and poverty," says Jane Lubchenco of Oregon State University, Corvallis, who co-chaired a report to business and industry.

Another troubling trend is the intense disturbance of global nutrient cycles. Excessive use of nitrogen fertilizers has inadvertently led to the eutrophication of estuaries, algal blooms, massive fish kills, and contamination of groundwater. "The impacts are very large, with direct and sig-

* "Millennium Ecosystem Assessment Synthesis Report," www.maweb.org

Choose Your Own World

What will ecosystems be like in 2050? That depends on decisions made today, so to give policymakers an idea of the consequences, a Millennium Ecosystem Assessment (MA) working group envisioned what life would be like under four types of broad policies. For each of these scenarios, they used standard computer models that predict changes in variables such as gross domestic product, water use, and food production. Where no models were available, they relied on expert opinion to assess the role of technological innovation, human health, and other factors.

Some observers were frustrated at the lack of quantification and reliance on expert opinion. But most say the scenarios are a useful thought exercise. "It's a way of motivating thinking and stimulating the imagination, even at national levels, about the choices involved in ecosystem changes," says Jeffrey Tschirley of the U.N. Food and Agriculture Organization in Rome. "Based on decisions you make, you can create a different world."

"Order from strength." Perhaps not as bad as *Blade Runner*, the world has fragmented into regional markets and alliances. Nations are obsessed with security issues, and the tragedy of the commons deepens. Every category of ecosystem services takes a nosedive, and the developing world bears the brunt of the damage.

"Global orchestration." Free trade and a good heart reign in this scenario. There's no focus on preventing environmental problems, but an emphasis on fighting poverty. The result is a huge boost in food and other provisioning services from developing countries. The costs are borne by regulating services—such as climate change—and a loss in cultural services, such as ecotourism.



"TechnoGarden." Al Gore would love this world—globally connected with green technology abounding and a focus on preventing ecosystem problems. Food and other provisions rise, although they are not maximized. Climate change, floods, and disease are less of a worry. The downside is that biodiversity continues to decline.

"Adapting mosaic." The emphasis here is on low-tech, local solutions. Regional politicians and institutions focus on watershed-scale ecosystems to maximize benefits and prevent problems. If it catches on widely, it pays off: Every type of ecosystem service improves in both developing and industrialized nations. —E.S.



nificant consequences for human well-being," Reid says.

The report documents numerous other examples of how humans create problems when they try to wring more out of an ecosystem. Farming shrimp degrades water quality; cutting down forests to make charcoal worsens flooding downstream; rice paddies, cows, and slash-and-burn agriculture all pump carbon into the atmosphere, changing climate in ways that could ultimately hurt farmers. "The key point is that not everything is win-win," Watson says. The harm can stretch down a river or across the ocean, when dust from degraded African soils worsens air quality in North America. And it can pass from generation to generation, when actions today—depleting soil, for instance—compromise the ability of ecosystems to deliver goods and services in the future.

The severity of the problems becomes more tangible when costs are tallied in dollars. The MA cites a litany of examples including \$2 billion spent to help communities recover from the crash of the Newfoundland cod fish-

ery in the early 1990s and more than \$70 billion worth of damage in 2003 from floods, fires, drought, and other disasters. Valuing the benefits of ecosystems, on the other hand, is still in its infancy. The MA didn't try to make such estimates itself but notes studies such as a 1998 estimate of \$346 million in benefits from protecting water quality in the Catawba River, North Carolina.

Nor does the MA recommend particular solutions to broad environmental problems. Instead it lays out four visions of the future (see sidebar, above) that might result from various kinds of policies, such as changing the nature of agricultural subsidies to promote land conservation or investing heavily in green technologies. Effective action will be required, the report urges, and soon: Even though



world population is expected to stabilize by 2050, the MA predicts that the challenges will be heightened by climate change and ever-more-voracious demand for resources.

Measuring the intangible

The idea for the global assessment was hatched in 1998 at the World Resources Institute (WRI) in Washington, D.C., where Reid and others were interested in taking a look at the state of the world's ecosystems at the turn of the millennium. Lingered in their minds was the fate of a previous overview, called the Global Biodiversity Assessment (GBA), that had gone essentially unnoticed after its release in 1995 (*Science*, 8 September 2000, p. 1676).

They quickly decided that the way to make a bigger impact would be to focus on goods and services. "You can talk about how ecosystems operate to policymakers, and their eyes glaze over. But if you mention services, they perk up," says Hal Mooney of Stanford University, a lead MA participant.

Watson, a veteran of many assessments—including the GBA—was deeply involved with the much more successful Intergovernmental Panel on Climate Change (IPCC) and decided to take a page from its design, which included winning broad support for the project from the get-go. Watson and Reid approached their target audiences, such as the Convention on Biological Diversity, and involved them on the board and in the design of the project. Various "stakeholders" chimed in on what would be of value to them.

Another key decision was to combine the big picture with many local assessments, ranging in scale from Peruvian villages to all of southern Africa. The reason for including targeted studies, says Reid, is that some ecosystem problems and services such as cultural benefits of green space are local, and decision-makers need specific information. For example, the Southern Africa assessment, the first of 17 such studies to be published, found that the region as a whole has an adequate supply of fuelwood but that there are several areas with severe shortages. At the same time, decisionmakers need to know what's going on globally, as decisions at a larger scale (such as government intervention in the international timber market) affect local communities.

Over the course of a year, a committee of about 90 scientists hashed out a conceptual framework: a box and arrows

Service. Walter Reid spent 6 years leading a dozen staff and 1300 volunteers.

Over the course of a year, a committee of about 90 scientists hashed out a conceptual framework: a box and arrows

that laid out the components of ecosystems and how to assess the services they provide. Definitions were ironed out for terms such as biodiversity (“the variability among living organisms from all sources ... and the ecological complexes of which they are a part”) and human well-being (“a combination of physical and social factors including shelter, health, freedom, and the ability to provide for children.”)

Unpredictable Changes

Dead zones. Nutrient loading can cause sudden, widespread algal blooms that suffocate animals.

Fisheries collapse. After centuries of fishing, cod stocks in the Atlantic collapsed in 1992.

Alien invaders. Zebra mussels and other invasive species can be a complete surprise.

Forest feedback. Deforestation dries out a region, which can mean even more forest loss.

“Getting everyone to agree on definitions gets rid of the tower of Babel phenomenon,” says Shahid Naeem of Columbia University in New York, enabling ecologists to collaborate with anthropologists and economists, for instance.

In an attempt to bring clarity to the nascent field of ecosystem services, the committee divided benefits into four categories: provisioning, regulating, cultural, and basic support (see box, p. 41). Mooney says this methodological framework, laid out in a 2003 book,[†] has been adopted widely, for example, by an international biodiversity consortium called Diversitas in Paris, France. This standardization should facilitate comparisons of ecosystem services between countries, notes Les Firbank of the Center for Hydrology and Ecology in Lancaster, U.K., who was not involved.

When the actual assessment got under way in April 2001, participants soon found themselves struggling with a critical lack of data. For example, remote-sensing data cover most of the world, but it was possible to extract an accurate description of land cover for only those parts of the world for which scientists had verified the satellite data. The whole exercise “gives us an understanding of how much data we don’t have—and the really poor quality of data that we do have,” says MA board member Jeffrey Tschirley of the U.N. Food and Agriculture Organization (FAO) in Rome.

Then came the equally tricky task of trying to link the state of ecosystems to human well-being in a rigorous way. “That’s a surprising and unfortunate gap,” Reid says. Most of the evidence is anecdotal, such as studies of the cost to replace the loss of natural pollinators or pest-eating bats. And although it’s

[†] *Ecosystems and Human Well-Being: A Framework for Assessment* (Island Press).

well established how to measure the costs and benefits of marketed ecosystem services, such as timber, much less is known about how to do that for other benefits, like the clean water provided by healthy watersheds.

Technical reports from the four working groups will be published this year, as will syntheses aimed for the health and business sectors and four sponsoring conventions. All will be available on the Web site www.maweb.org.

On the agenda

Although the MA reports don’t contain any breaking news for ecologists, participants say the MA’s main accomplishment is a consensus document that emphasizes that human well-being depends on healthy ecosystems. They hope that, like the IPCC, that consensus will help raise the issue higher on the priority lists of nations.

Beyond the rhetorical value, the collected data will likely be useful for national and local decision-makers, such as those calculating conservation subsidies to farmers or devising certification schemes for sustainable forestry. But that won’t happen on its own, so key MA participants are trying to ensure that the report doesn’t gather dust. “The outreach task for this is just huge, and we’re just at the beginning,” says Stephen Carpenter of the University of Wisconsin, Madison, who co-chaired the scenarios report. Robert Scholes of the Council for Scientific and Industrial Research in South Africa says he’s been briefing policymakers ever since the southern African assessment was published 6 months ago, targeting key ministers and giving two to three talks a month. He expects to keep up the pace for at least a year more.

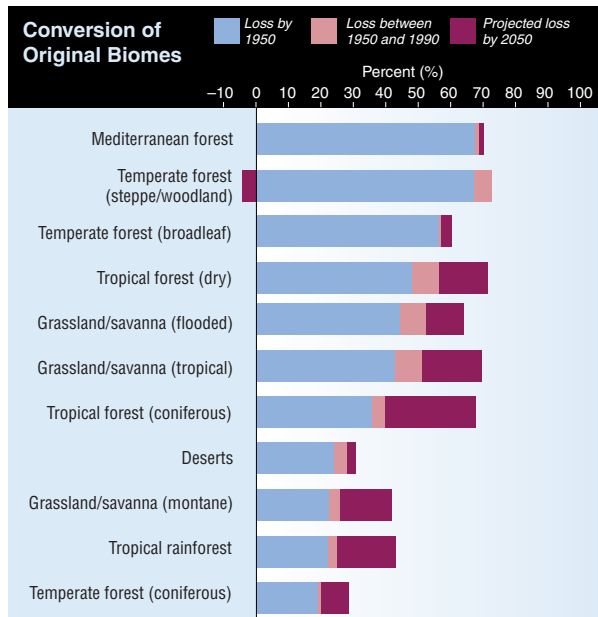
The convention leaders say that the MA will help them carry out their own work. In the Ramsar convention, for example, Bridgewater explains that the MA has better defined key terms in the wetlands treaty. Member nations had agreed to foster “wise use” of their wetlands and ensure that “ecological character” does not change; the framework has helped make that more explicit by focusing on long-term delivery of ecosystem services.

Although scientists and policymakers have lauded the MA, some are frustrated at the limits of its conclusions. The MA finds that ecosystems are being degraded, for

example, but it couldn’t say anything specific about the pace of that degradation or what levels of use are sustainable. That uncertainty can make it tougher to implement policies that cause economic losses in the short-term. The threat of various catastrophic ecosystem failures might make policymakers think twice, but no one knows how close society is to the brink. The report is “pretty anecdotal when it comes to thresholds,” says Richard Norgaard, an environmental economist at the University of California, Berkeley. That’s not the MA’s fault but more a reflection of the immature state of the science, he adds.

What’s needed to help design effective policy is more quantification and dollar values of ecosystem services, says FAO’s Tschirley. “That’s where there is a payoff; that’s when it gets value for development and when things can be planned.”

The MA was planned to provide a baseline for future assessments but not to organize them. Reid says that the working assumption is that if governments and the private sector find that



Going, going. Major ecological communities, or biomes, will be turned to farms and other purposes over the next 50 years.

round one was useful, they’ll pony up for more. “If this really succeeds,” Reid says, “then people will want to follow the model.” Many scientists say that follow-ups will be key, as it took several rounds for the IPCC to work out its kinks. Follow-up assessments would also be a way to confirm trends in ecosystem services.

Regardless, a key legacy is the effect on ecologists and other environmental scientists. “It’s been a really big force for shifting mindsets in the science community,” says ecologist Gretchen Daily of Stanford University. “There’s a whole community of people who are now abuzz with this effort.”

—ERIK STOKSTAD