Ecosystem Services: An Overview

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Outline

- Findings from the Millennium Ecosystem Assessment
- Indicators from State of the Nations Ecosystems
- Change is the thing
- Research Conundrum
Ecosystems

- Biological communities and their physical environment
- Scale is a function of the intent of the analysis
- People and infrastructure should be thought of as part of ecosystems, not apart from them
Ecosystem Services

- Work, or functioning, that ecosystems do from which we benefit
- Benefit can be direct or indirect
- An unabashedly anthropocentric concept at its core
- Originally articulated to point out that there are things that ecosystems provide that we depend on, but do not pay for (until we have to replace them)
- This concept has grown to recognize that services can be either outside or inside of existing markets
Millennium Assessment Focus: Ecosystem Services - Benefits obtained from ecosystems

**ECOSYSTEM SERVICES**

**Provisioning**
- Food
- Freshwater
- Wood and Fiber
- Fuel
- ...

**Supporting**
- Nutrient Cycling
- Soil Formation
- Primary Production
- ...

**Regulating**
- Climate Regulation
- Flood Regulation
- Disease Regulation
- Water Purification
- ...

**Cultural**
- Aesthetic
- Spiritual
- Educational
- Recreational
- ...
MA Finding #1

- Over the past 50 years, humans have changed ecosystems more rapidly and extensively than in any comparable period of time in human history.
- This has resulted in a substantial and largely irreversible loss in the diversity of life on Earth.
Unprecedented change: Ecosystems

- More land was converted to cropland since 1945 than in the 18th and 19th centuries combined
- 20% of the world’s coral reefs were lost and 20% degraded in the last several decades
- 35% of mangrove area has been lost in the last several decades
- Amount of water in reservoirs quadrupled since 1960
- Withdrawals from rivers and lakes doubled since 1960
Land-Cover and Land-Use Change

- Perhaps the most consequential human-driven change of Earth’s important characteristics
  - About half of original forest area converted to agricultural production
  - Roughly doubled the amount of biologically available nitrogen
  - Increases in atmospheric concentrations of CO₂
  - Biggest contribution to loss of biological diversity
Figure 1: Main areas of deforestation and forest degradation over the last twenty years (1980-2000)
Implications

- Rationale emphasized documentation of services for purpose of understanding tradeoffs
- This is possible for some tradeoffs:
  - Increase in timber production against carbon sequestration potential
  - Increase in agricultural output against a variety of other ecosystem services
- Not possible for others because of lack of information on state, even though we understand processes
MA Finding #2

- The changes that have been made to ecosystems have contributed to substantial net gains in human well-being and economic development.
  - Since 1960, while population doubled and economic activity increased 6-fold, food production increased 2 ½ times, food price has declined, water use doubled, wood harvest for pulp tripled, hydropower doubled.
  - But these gains have been achieved at growing costs that, unless addressed, will substantially diminish the benefits that future generations obtain from ecosystems.
Degradation and unsustainable use of ecosystem services

- Approximately 60% (15 out of 24) of the ecosystem services evaluated in this assessment are being degraded or used unsustainably.
- The degradation of ecosystem services often causes significant harm to human well-being and represents a loss of a natural asset or wealth of a country.
Most direct drivers of degradation in ecosystem services remain constant or are growing in intensity in most ecosystems.
Degradation of ecosystem services often causes significant harm to human well-being

The total economic value associated with managing ecosystems more sustainably is often higher than the value associated with conversion.

Conversion may still occur because private economic benefits are often greater for the converted system.
The degradation of ecosystem services represents loss of a capital asset

- Loss of wealth due to ecosystem degradation is not reflected in economic accounts
- Ecosystem services, as well as resources such as mineral deposits, soil nutrients, and fossil fuels are capital assets
- Traditional national accounts do not include measures of resource depletion or of the degradation of these resources
- A country could cut its forests and deplete its fisheries, and this would show only as a positive gain in GDP without registering the corresponding decline in assets (wealth)
- A number of countries that appeared to have positive growth in net savings (wealth) in 2001 actually experienced a loss in wealth when degradation of natural resources were factored into the accounts
The State of The Nation's Ecosystems

Measuring the Lands, Waters, and Living Resources of the United States
### What Indicators Are Used To Describe Farmlands?

<table>
<thead>
<tr>
<th>SYSTEM DIMENSIONS</th>
<th>CHEMICAL AND PHYSICAL CONDITIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Cropland</strong></td>
<td>How much land is used directly for production of crops and livestock?</td>
</tr>
<tr>
<td><strong>The Farmland Landscape</strong></td>
<td>How much of the farmland landscape is forest, grasslands and shrublands, wetlands, or urban and suburban?</td>
</tr>
<tr>
<td><strong>Fragmentation of Farmlands Landscapes by Development</strong></td>
<td>How intermingled are croplands and urban and suburban development?</td>
</tr>
<tr>
<td><strong>Shape of &quot;Natural&quot; Patches in the Farmland Landscape</strong></td>
<td>How much of the “natural” area in farmlands is in patches of different shapes?</td>
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<tr>
<td><strong>Nitrate in Farmland Streams and Groundwater</strong></td>
<td>How much nitrate is there in farmland streams and groundwater?</td>
</tr>
<tr>
<td><strong>Phosphorus in Farmland Streams</strong></td>
<td>How much phosphorus is there in farmland streams?</td>
</tr>
<tr>
<td><strong>Pesticides in Farmland Streams and Groundwater</strong></td>
<td>How many pesticides are found in farmland streams and groundwater, and how often do they exceed federal standards and guidelines?</td>
</tr>
<tr>
<td><strong>Soil Organic Matter</strong></td>
<td>How much organic matter is there in cropland soils?</td>
</tr>
<tr>
<td><strong>Soil Erosion</strong></td>
<td>How much cropland is subject to erosion by wind or water?</td>
</tr>
<tr>
<td><strong>Soil Salinity</strong></td>
<td>How much cropland soil has high salt levels?</td>
</tr>
</tbody>
</table>

**Legend:**
- ● All Necessary Data Available
- ○ Partial Data Available
- ❌ Data Not Adequate for National Reporting
- ❔ Indicator Development Needed
<table>
<thead>
<tr>
<th>BIOLOGICAL COMPONENTS</th>
<th>Can we report trends? Are there other useful reference points?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil Biological Condition</td>
<td>What is the condition of the microscopic animal communities in cropland soils?</td>
</tr>
<tr>
<td>Status of Animal Species in Farmlands Areas</td>
<td>What is the condition of wildlife in areas that are heavily dominated by farmlands?</td>
</tr>
<tr>
<td>Native Vegetation in Areas Dominated by Croplands</td>
<td>In areas that are heavily dominated by croplands, is most of the remaining non-cropland vegetation native or non-native?</td>
</tr>
<tr>
<td>Stream Habitat Quality</td>
<td>What is the quality of the habitat in farmland streams?</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>HUMAN USES</th>
<th></th>
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<tbody>
<tr>
<td>Major Crop Yields</td>
<td>How has the per-acre yield of major crops changed over time?</td>
</tr>
<tr>
<td>Agricultural Inputs and Outputs</td>
<td>How have farm output and the inputs (pesticides, fertilizers, labor, land, etc.) needed to produce that output, changed over time?</td>
</tr>
<tr>
<td>Monetary Value of Agricultural Production</td>
<td>What is the value of the nation's production of crops and livestock?</td>
</tr>
<tr>
<td>Recreation on Farmlands</td>
<td>How much recreation takes place on farmlands?</td>
</tr>
</tbody>
</table>

All Necessary Data Available | Partial Data Available | Data Not Adequate for National Reporting | Indicator Development Needed
Cropland Estimates

Data Source: USDA National Resources Conservation Service, National Resources Inventory (NRI) program; USDA National Agricultural Statistical Service, Census of Agriculture; USDA Economic Research Service (ERS); Multi-Resolution Land Characterization Consortium (MRLC) and the U.S. Geological Survey. Coverage: lower 48 states. Conservation Reserve Program acreage has been removed from all but the ERS data set; also, some CRP lands may be included in the National Land Cover Data.
Change in Ecosystem Area (Compared to 1955)

Data Not Adequate for National Reporting on
- Extent of brackish coastal waters

Partial Indicator Data: Forests, Croplands, Grasslands/Shrublands, Urban/Suburban, Freshwater Wetlands

- Urban
- Croplands
- Freshwater Wetlands
- Forests

Data Source: USDA Forest Service (forest trends), USDA Economic Research Service (cropland and urban area trends), U.S. Fish and Wildlife Service (FWS, freshwater wetlands trends. Coverage: lower 48 states.)
Crop Yields: Corn, Soybeans, and Wheat

Agricultural Outputs

Agricultural Inputs per Unit of Output

Yield of Total Nitrogen from Major Watersheds (1996–1999)

Total Nitrogen (pounds of nitrogen per sq. mile per year)
- Data Not Available
- Less than 10
- 10-600
- 600-1,500
- 1,500-3,000
- 3,000-10,000

Are We Showing Ecosystem Services?

- Process not set up that way
- But identification and consensus on indicators is explicitly a value-laden process
- Saying what it is that broad spectrum of stakeholders value about ecosystems
- So in fact, much of what we report is consistent with notion of services
Change is the Thing

- Can certainly document the big tradeoffs: agricultural productivity vs. carbon storage (globally)
- Agricultural productivity vs. availability of fresh water for other uses
- But documentation on smaller, more detailed scales is difficult, even when we are confident about underlying processes
Implications for Research and a Conundrum
Implications for Research

- Need to be able to document change - periodic snapshots of state of ecosystems (and their processes) not good enough
- Need process-level understanding of tradeoffs and balance sheet
- Consistently derived time series are absolutely crucial
Capacity to make the measurements is growing - technological advancements in observations, data management and sharing, modeling
Commitment to make the measurements and share the information is shrinking - GAO findings
Suggests we have a major research problem - need to shore up the infrastructure at same time as pursue the new science