Agricultural Ecosystem Services and the Costs of Food Production

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Exploring the True Cost of Food: IOM Workshop
Washington, DC, April 23-24, 2012
Agricultural ecosystems are managed for *provisioning ecosystem services*

- **Provisioning**
  - Food
  - Fiber
  - Fuel

- **Regulating**
  - Climate
  - Water
  - Habitat

- **Cultural**
  - Aesthetics
  - Recreation
  - Sci. knowl.

**Supporting** (enable other ES)
- Soil formation, nutrient cycling, primary productivity

*Millennium Ecosystem Assessment, 2005*
Agriculture relies upon ES inflows and creates ES outflows—not all desirable

**Services TO**
- Climate/air regulation
- Water provision
- Soil provision
- Pollination
- Pest regulation
- Genetic diversity

**Services FROM**
- Food, fiber, bioenergy
- Aesthetics (some farms)
- Recreation
- Carbon sequestration
- Biodiversity conservation

**Disservices TO**
- Pests & diseases

**Disservices FROM**
- Water pollution
- Health risks from hormone, agrochemicals, antibiotics
- Climate change from GHG
- Habitat loss for beneficials
- Aesthetics of some farms

For regulating ES, effect of agriculture depends on balance

- **Climate regulation**
  - If farming sequesters greenhouse gases on net, then effect is to mitigate climate change.
  - If farming adds GHGs on net, then effect is to contribute to climate change.

- **Water quality regulation**
  - If farming maintains nutrient flows in place, then water quality effect may be minimal.
  - Ecosystem Disservices occur when balance from “regulating services” is upset.
Agriculture is a transformation process

- Costs to ecosystem services can occur at
  - Input side: Depletion of natural capital (which generate ES)
  - Output side: Contamination of natural capital (which generates disservices)
- Markets often absent for ecosystem services
Economic valuation of ES

- Economic values result from relation between supply and demand
  - Not same as intrinsic values (Heal, 2000)
- Non-market valuation methods attempt to simulate supply & demand
- Key principles (adapted from Pearce 1998; Bockstael et al 2000):
  - Marginal changes from baseline
  - Budget constraints limit choices
  - Decision maker decides on best alternative
Steps to put dollar values on ES linked to food production

- Quantity measurement of each $\Delta ES_i$
  - Baseline production process
  - Alternative feasible processes
  - Compare to measure feasible $\Delta ES_i$
- Value estimation for unit of specific $\Delta ES_i$
  - Demand: Willingness to pay (WTP)
    - What people pay for similar change in $ES_i$ levels
  - Supply: Willingness to accept (WTA)
    - Changed practices change production cost
Common approaches to ES valuation

- Cost-based methods
  - Cost of remediation
  - Factor substitution
  - Production function
  - Travel cost / cost of illness

- Stated preference
  - Contingent valuation / ranking

M. Freeman III 2003; Millennium Ecosys Assessment 2003
## Indicative valuation methods for selected ES

<table>
<thead>
<tr>
<th>Ecological service</th>
<th>Focus</th>
<th>Method</th>
<th>Scale</th>
<th>External cost?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Erosion control</td>
<td>Siltation of waterways, reservoirs</td>
<td>Cost of remediation</td>
<td>Watershed</td>
<td>Yes</td>
</tr>
<tr>
<td>Erosion control</td>
<td>Crop yield</td>
<td>Production function</td>
<td>Farm</td>
<td>No</td>
</tr>
<tr>
<td>Climate regulation</td>
<td>Climate</td>
<td>Contingent valuation</td>
<td>Global</td>
<td>Yes</td>
</tr>
<tr>
<td>Pollination</td>
<td>Crops</td>
<td>Production function</td>
<td>Local</td>
<td>Partly</td>
</tr>
<tr>
<td>Pollination/ genetic diversity</td>
<td>Wild flowering plants – pharmaceutical resource</td>
<td>Factor cost</td>
<td>Regional</td>
<td>Yes</td>
</tr>
<tr>
<td>Recreation</td>
<td>Agro-tourism</td>
<td>Travel cost</td>
<td>Regional</td>
<td>Partly</td>
</tr>
</tbody>
</table>
Complication #1: ES are produced as joint products, so not additive

- Consumers experience ES individually
- But ES are jointly produced alongside marketed food products
  - Changing one ES may require changing production process, with repercussions for all ES
  - Farm-level marginal cost of changing 2nd ES may be small, once 1st ES to be changed
    - Example: Reducing nitrogen fertilizer use to cut GHG emissions from nitrous oxide (N₂O) also reduces nitrate (NO₃) leaching
How farming practice changes link to environmental outcomes

Agricultural practices

- Complex rotation
- Less tillage
- Less fertilizer input
- Less pesticide input

Intermediate environmental changes

- Less soil erosion
- Less phosphorus loading to waters
- Less greenhouse gas emissions
- Less N loss
- Less pesticide into the air

Off-farm ES consequences

- Reduced drain dredging
- Lower incidence of flooding
- Better recreation use of waters
- Mitigated global warming
- Improved drinking water quality
- Air quality
- Reduced health risk
- Higher population of insects and animals

Complication #2: ES values vary by time, place

- Supply-demand balance tied to relative scarcity
- Scale of ES affects implied market S & D
  - On-farm (e.g., soil quality)—internal to farm
  - Local or “landscape” scale—regulating ES
    - Water quality, pollination & pest control services
    - Local abundance & demand drives values
  - Global scale ➔ global values
    - Climate regulation
- Future values may vary with relative scarcity
Complication #3: Measurement costs

- Heterogeneity of settings & practices makes ES outcomes highly variable, costly to observe.
  - Settings vary (e.g., site vulnerability, weather)
  - Practices vary (even timing of an activity can affect outcomes)

- Simulation modeling is used in research, but validity for broad range of application with legal ramifications has not been tested.
Incorporating ES values into nonmarket costs of food

- Not all ES values are external to food costs.

- ES **quantity** changes depend upon **how and where** food was produced.

- ES **unit values** depend upon relative scarcity of specific ES in their implicit “markets”
  - “Markets” range in scale from local to global