Key Questions

• What is an ecosystem services approach to forest management?
• How can one understand and model “forest health” within an ecosystem services approach?
• What are the ecosystem services that could be impacted by releasing trees protected from pests and pathogens using biotechnology (and what are those impacts)?
• What ecosystem services measures, methodologies, and analytical approaches are potentially for examining this issue?
Ecosystem Services and Values

- Ecosystem services may be defined as the aspects, flows or conditions of natural systems that benefit society.
- The goal is a formal and quantifiable link between changes in ecosystems and changes in human well-being.
- Ecosystem services can provide benefits to people both in and out of organized markets.
- Non-market values reflect the benefit of goods and services not exchanged in markets, e.g., flood or erosion control, wildlife habitat, aesthetics, outdoor recreational opportunities.
- Methods are well established. For a primer, see: https://nespguidebook.com/.
An Ecosystem Services Approach

• The ecosystem services approach allows one to inform decision based on the social benefits received from ecosystems.

• Three core questions define an ecosystem services framework.
  • How does a policy, decision, or action affect ecological conditions?
  • How do changes in ecological conditions lead to changes in final ecosystem services (the things that are valued directly)?
  • How do changes in final ecosystem services affect benefits or costs to individuals or groups?

• Grounded in a structural understanding of causal linkages between ecosystem processes and human benefits.
Introductions to Forest Ecosystem Services

Evaluating Tradeoffs Among Ecosystem Services in the Management of Public Lands

Jeffrey D. Kline and Marisa J. Mazzotta

Defining an Economics Research Program to Describe and Evaluate Ecosystem Services

Jeffrey D. Kline
Classification of Ecosystem Service Values (Economic)

Total Economic Value (TEV)

- Use values
  - Direct use values
    - Food supply (e.g., fishing)
    - Recreational (e.g., wildlife watching)
    - Educational (e.g., research opportunities)
  - Indirect use values
    - Property protection (e.g., flood risk)
    - Pollination
    - Climate regulation (cooling by urban trees)

- Non-use/passive values
  - Existence values
  - Bequest values
  - Altruistic values
    - Satisfaction from the existence of the resource
    - Satisfaction from the resource being available to future generations
    - Satisfaction from the resource being available to others in the current generation

How Ecosystems Affect People—The Causal Chain

• An outcome can provide human benefit in three ways.
  • **Direct or final effect** on benefits; such outcomes directly affect welfare without intermediate effects on other outcomes. Example: Timber to forest products firms; forest aesthetics to hikers.
  • **Indirect or intermediate effect** on benefits; such outcomes only affect welfare through causal influences on other outcomes. Example: carbon sequestration in forests.
  • Both directly and indirectly (**dual effect**).

• Valuation requires quantification of changes in final ecosystem services (these are the things people value).

• An understanding of only intermediate changes is insufficient to estimate value, unless causal chains can predict effects on the final services valued by people.
Ecosystem Services and Forest Health

• What are the aspects of forests (including forest health) that benefit (or harm) people and how?

• Forest “health” may be conceptualized two ways:
  1. A general way to characterize ecological structure and function through which forests provide ecosystem services,
  2. A holistic metric valued directly by people, e.g., as might be quantified using an index of biotic integrity (IBI) in aquatic systems

Ecosystem Services, Forest Health and Biotechnology – A Structural Illustration

• Benefits may be conceptualized formally using an illustrative indirect household production utility function.

\[ V( X^*_m(F[s, b]), X^*_h(F[s, b], X^*_m(F[s, b])), F[s, b] ) \]

• \( F[s, b] \) = ecosystem goods and services as a function of forest attributes \( s \) (together “forest health”) and biotechnology attributes \( b \).

• \( X^*_m \) = market goods & services purchased at prices \( P_m \) and produced by firms using \( F[s, b] \)

• \( X^*_h \) = non-market goods “produced” by the household using \( X^*_m \) and \( F[s, b] \) (e.g., outdoor recreation; living in forested areas).

• Non-forest variables (e.g., prices) are suppressed from \( V(\cdot) \).

\[ \frac{dV(\cdot)}{db} = \Delta \text{ in ecosystem service benefits caused by } \Delta \text{ in biotechnology use — these arise though multiple channels.} \]
Effects on Market Goods & Services

- Biotechnology use may affect demand for market goods (increasing or decreasing), due to consumer reactions.
- May affect supply (firms’ production costs), due to changes in forest inputs to firms.
- Combined demand and supply changes influence prices.
- Benefit changes can occur for consumers or producers.


Effects on Non-Market Goods & Services

• Changes in forest health and biotechnology use can affect benefits realized via non-market goods and services.

• Effects such as change in tree canopy and reduction in dead or dying trees can affect property protection, recreation, aesthetic, and other non-market ecosystem services.


• Biotechnology use can reduce production or demand for non-market ecosystem services, e.g., due to perceived hazards or quality changes.

Effects on Non-Use Benefits

• Changes in forest health and biotechnology use can affect non-use benefits (e.g., existence or bequest values).

• People may realize non-use benefits from increases in tree cover, preservation of pest-ravaged species (e.g., American Chestnut), wildlife habitat, forest biodiversity, etc.


• Biotechnology use can reduce non-use benefits (e.g., due to existence values for natural systems and perceived risks to human health, natural landscapes and plants, etc.).

• Net effect is an empirical question.
### Partial List of Ecosystem Services Potentially Affected by Biotechnology

<table>
<thead>
<tr>
<th>Forest Ecosystem Service Potentially Affected</th>
<th>Primary Causal Pathway(s) (Secondary market effects not included to avoid double-counting)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Timber &amp; Non-Timber Forest Products</td>
<td>Market (individuals and firms)</td>
</tr>
<tr>
<td>Recreational Services</td>
<td>Non-Market (individuals)</td>
</tr>
<tr>
<td>Wildlife &amp; Biodiversity (Non-Recreation)</td>
<td>Non-market (individuals); Market (individuals &amp; firms)</td>
</tr>
<tr>
<td>Soil Stabilization &amp; Water Quality</td>
<td>Non-market (individuals); Market (individuals &amp; firms)</td>
</tr>
<tr>
<td>Aesthetics, Cultural, Quality of Life</td>
<td>Non-market (individuals)</td>
</tr>
<tr>
<td>Air Quality (e.g., smoke due to fires)</td>
<td>Non-market (individuals); Market (individuals &amp; firms)</td>
</tr>
<tr>
<td>Fire Risk (to people and property)</td>
<td>Non-market (individuals); Market (individuals &amp; firms)</td>
</tr>
<tr>
<td>Carbon Sequestration (intermediate)</td>
<td>Indirect Market and Non-market Only (individuals and firms)</td>
</tr>
<tr>
<td>Non-Use (not included in the above)</td>
<td>Non-market (individuals)</td>
</tr>
</tbody>
</table>

- Understanding pathways (causal chains) and direct vs. indirect benefits is required to avoid double-counting.
Quantifying Effects: Ecosystem Services Analysis

• General approaches for ecosystem services assessment are outlined in: [https://nespguidebook.com/](https://nespguidebook.com/).


• Basic Steps of an ecosystem services analysis include
  
  • **Scoping**: Establishes conceptual linkages among actions, ecological systems, ecosystem services and values to different groups.
  
  • **Assessment & Quantification**: Formalizes causal chains, identifies ecosystem service indicators and ecological production functions; quantifies changes in ecosystem services.
  
  • **Valuation**: Quantifies effects on benefits (or value) realized by different beneficiary groups.
Linking Actions to Outcomes: Ecological Production Functions

**Management Alternatives**
- Mechanical Thinning (Site A – Lowland)

**Ecological Changes**
- Fire
  - Fire Severity (% mortality)
  - Fire Return interval (years)
  - Fire Burnt Area (km²)
- Air Quality
  - Particulates
  - Visibility

**Forest Structure**
- Understory Density (Index)
- Horizontal Connectivity (Index)
- Total Forest Area (km²)

**Carbon Models**
- Standing Carbon Stocks (kg/m³)
- Rate of Carbon Sequestration (kg/year)
- Carbon Sequestered in Forest Products (kg)

**Air Plume Models**
- Ecosystem Services
  - Respiratory Health
  - Commuter Visibility
  - Reduction of Fire Risk
  - Climate Stability
  - Timber

**Air Quality**
- Particulates (µg/m³)
- Visibility (miles)
## Linking Outcomes to Values: Common Economic Valuation Methods

<table>
<thead>
<tr>
<th>Valuation Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Revealed Preference</strong></td>
<td></td>
</tr>
<tr>
<td>Market Demand</td>
<td>Derives value from household’s or firm’s demand for the good or service itself</td>
</tr>
<tr>
<td>Factor Input Methods</td>
<td>Derives value based on the contribution to the production of market goods</td>
</tr>
<tr>
<td>Hedonic Wage &amp; Price Methods</td>
<td>Derives an implicit value from market prices of related goods or job wages</td>
</tr>
<tr>
<td>Recreation Demand Methods</td>
<td>Derives an implicit value based on observed recreational behaviors</td>
</tr>
</tbody>
</table>
# Common Economic Valuation Methods

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<tbody>
<tr>
<td><strong>Revealed Preference:</strong></td>
<td></td>
</tr>
<tr>
<td>Cost Avoided and Defensive Behavior</td>
<td><em>Damage Costs Avoided</em>: Value is inferred from the direct and indirect expenses incurred as a result of damage to the built environment or to people.</td>
</tr>
<tr>
<td></td>
<td><em>Averting Behavior / Defensive Expenditures</em>: Value is inferred from costs and expenditures incurred in mitigating or avoiding damages.</td>
</tr>
<tr>
<td></td>
<td><em>Replacement / Restoration Cost</em>: Value is inferred from potential expenditures incurred from replacing or restoring an ecosystem services.</td>
</tr>
<tr>
<td><strong>Cost avoided and defensive behavior methods are able to estimate well-defined values only under restrictive circumstances – generally these provide upper or lower bounds only.</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Stated Preference</strong></td>
<td></td>
</tr>
<tr>
<td>(only way to estimate non-use values)</td>
<td><em>Contingent Valuation</em>: Creates a hypothetical market by asking survey respondents to state their willingness-to-pay or willingness-to-accept payment for an outcome (open-ended), or by asking them whether they would choose actions or policies with given outcomes and costs (discrete choice).</td>
</tr>
<tr>
<td></td>
<td><em>Discrete Choice Experiments</em>: Creates a hypothetical market by asking survey respondents to choose among multi-attribute bundles of goods with associated costs and derives value using statistical models.</td>
</tr>
<tr>
<td><strong>Benefit Transfer</strong></td>
<td></td>
</tr>
<tr>
<td>(Unit &amp; Function)</td>
<td><em>Benefit Transfer (Unit &amp; Function)</em>: Use of results from pre-existing primary studies at one or more sites (called study sites) to predict value for other, typically unstudied sites (called policy sites).</td>
</tr>
</tbody>
</table>
The Role of Risk and Uncertainty

- The primary *anticipated and/or intended* effects of biotechnology (that reduces pest vulnerability) on forest ecosystem service benefits are often positive, except:
  - Individuals can have reduced demand for market and non-market services related to the use of biotechnology and perceived risks,
  - Biotechnology use could have unintended consequences that could negate or reverse these gains, or cause losses elsewhere.

- Risk and uncertainty affect biophysical outcomes and values under uncertainty.


- The net effect on ecosystem service values are unclear.
Guidance for Identifying, Quantifying & Valuing Ecosystem Services


- Many other sources exist as well.
Final Comments

• An ecosystem services framework provides a structured approach through which to evaluate the effects of forest biotechnology on social benefits.

• The focus of ecosystem services analysis is the various pathways through which benefits or costs occur.

• Methods exist for all components of analysis, but estimation of empirical relationships can sometimes present challenges.

• Positive and negative effects on ecosystem service values are likely. Whether net effects are positive is an empirical question.

• Risk and uncertainty are important components of ecosystem services quantification and valuation.
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