Ecosystem Service Valuation: Concepts, Methods and Applications

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Natural Capital Project
Stanford University
• **What** is ecosystem service valuation?
• **Why** value ecosystem services?
• **How** to value individual ecosystem services
  – Methods
  – Examples
• **How** to apply ecosystem service valuation in benefit-cost analysis
Outline

• **What** is ecosystem service valuation?
• Why value ecosystem services?
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  – Methods
  – Examples
• How to apply ecosystem service valuation in benefit-cost analysis
What is value / valuation?

Value
• The monetary worth of something
• Relative worth, utility, or importance

Valuation
• The act or process of valuing
• Judgment or appreciation of worth or character
Ecosystem Services: benefits people obtain from ecosystems

<table>
<thead>
<tr>
<th>Provisioning Services</th>
<th>Regulating Services</th>
<th>Cultural Services</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Food</td>
<td>- Climate regulation</td>
<td>- Aesthetic</td>
</tr>
<tr>
<td>- Fresh water</td>
<td>- Flood regulation</td>
<td>- Spiritual</td>
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<tr>
<td>- Wood and fiber</td>
<td>- Disease regulation</td>
<td>- Educational</td>
</tr>
<tr>
<td>- Fuel</td>
<td>- Water regulation</td>
<td>- Recreational</td>
</tr>
<tr>
<td>- ...</td>
<td>- ...</td>
<td>- ...</td>
</tr>
</tbody>
</table>

Supporting Services

- Nutrient cycling
- Water cycling
- Soil formation
- Provision of habitat
- Primary production
- ...

(Millennium Ecosystem Assessment)
Value of ecosystem services

• Value of ecosystem services depends on “human wellbeing” derived from nature
  – safety
  – material needs
  – health
  – spiritual satisfaction
  – social relations

• Monetary unit is used as a common metric to compare aspects of wellbeing
  – Widely recognized, comparable to other services
  – Easily incorporated into decision-making

It’s not all about money, it’s human wellbeing!
Categories of ecosystem service value

Total Economic Value

Use value
- Direct use value
  - Example: Timber
  - Example: Recreation
- Indirect use value
  - Example: Water purification
  - Example: Carbon sequestration

Non-use value
- Option value
  - Example: Soil fertility
  - Example: Biodiversity
- Existence value
  - Example: Rare species

Pagiola et al, 2004
Ecosystem service valuation

- Decisions
  - Institutions
  - Ecosystems
  - Value
  - Services

- Incentives
- Information
- Actions & Scenarios
- Biophysical Models
- Economic & Cultural Models

Daily et al. 2009
Outline

• What is ecosystem service valuation?
• **Why** value ecosystem services?
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  – Methods
  – Examples
• How to apply ecosystem service valuation in benefit-cost analysis
1. Determine total flow of benefits from ecosystems

Left column: commonly measured economic value
- Grazing
- Timber and fuelwood

Right column: non-market and other economic value
- Carbon sequestration
- Watershed protection
- Non-timber forest products
- Recreation and hunting

Benefits from forest in Mediterranean Countries

Millennium Ecosystem Assessment

Pagiola, von Ritter & Bishop 2004
2. Evaluate benefits and costs of ecosystem interventions

Industrial & commercial benefit VS Development Cost
- Grazing
- Timber and fuel wood

Pagiola, von Ritter & Bishop 2004
2. Evaluate benefits and costs of Ecosystem interventions

- Industrial & commercial benefit
- Development Cost
- Carbon Sequestration
- Watershed protection
- Non-timber forest product
- Recreation

Timber and fuel wood
Grazing

Pagiola, von Ritter & Bishop 2004
3. Determine distribution of benefits

- Nutrient mitigation
- Flood control
- Sediment mitigation
- Upstream
- Watershed
- Conservation
- Soil erosion control
- Climate regulation

Carbon sequestration
Endangered species

Pagiola, von Ritter & Bishop 2004
4. Finance ecosystem conservation

Upstream Watershed Conservation

Erosion control
Climate regulation

Farmers and Foresters

Water purification
Flood control
Sediment mitigation

Water utility
Hydropower industry
Beverage company
Municipalities

Pagiola, von Ritter & Bishop 2004
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Valuation Method

Total Economic Value

Use value

Direct use value

Indirect use value

Option value

Non-use value

Existence value

Market-based valuation and Non-market valuation

Non-market valuation

Pagliola et al, 2004
Valuation methods in InVEST

**Market-based valuation**
- Direct & indirect market
  - Market price
  - Production function
  - Avoided Damages/Replacement Cost

**Non-market valuation**
- Surrogate market
  - Revealed Preference
    - Hedonic pricing
    - Travel cost
- Hypothetical market
  - Stated Preference
    - Contingent Valuation
    - Choice modeling

**Benefit Transfer**

Current InVEST

Supplemental analysis with InVEST output
Market price method

• Actual prices of goods/services
  – InVEST examples:
    • Timber, Fish, Non-timber forest products, Agricultural products
    • Hydropower, Wave energy, Wind energy
    • Carbon sequestration (permit price)
    • Recreation (travel cost)

*models in grey are under development
Avoided damages/ Replacement cost

• Costs incurred in the absence of the service, measuring prices of equivalent non-ecosystem services

– InVEST examples:
  • Nutrient retention (water treatment)
  • Sediment retention (dredging)
  • Carbon sequestration (social cost)
  • Coastal vulnerability / protection (property damages from erosion and flooding)
  • Storm peak mitigation (flooding damage)
Production function

• Values of ecosystem products or services that contribute to the production of commercially marketed goods.

– InVEST examples:
  • Crop Pollination
    (Index value of wild pollinator sites derived from index value of crops)

Credit: Flickr-Dluogs
<table>
<thead>
<tr>
<th>Method</th>
<th>ES type</th>
<th>InVEST model</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Market price</strong></td>
<td><strong>Provisioning</strong></td>
<td>Fish Aquaculture</td>
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<tr>
<td></td>
<td>Service</td>
<td>Managed Timber Production</td>
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<td>Wave Energy</td>
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<td>Hydropower Production</td>
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<td>Wind energy</td>
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<td>Agricultural Production</td>
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<td>Non-timber Forest Product Production</td>
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<td></td>
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<td>Recreation <em>(travel cost)</em></td>
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<tr>
<td><strong>Avoided damages/replacement</strong></td>
<td><strong>Regulating</strong></td>
<td>Carbon Sequestration</td>
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<tr>
<td>cost**</td>
<td>Service</td>
<td>Water for Irrigation</td>
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<td><strong>Production function</strong></td>
<td><strong>Regulating</strong></td>
<td>Nutrient Retention</td>
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<td>Coastal Vulnerability / Protection</td>
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<td>Storm Peak Mitigation</td>
</tr>
<tr>
<td><strong>Currently not valued</strong></td>
<td><strong>Cultural/Supporti</strong></td>
<td>Biodiversity/Habitat quality and rarity</td>
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<td></td>
<td>ng /Regulating</td>
<td>Habitat risk assessment</td>
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<tr>
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<td>Services</td>
<td>Aesthetic view</td>
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*models in grey are under development*
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**Benefit Transfer**

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Current InVEST

Supplemental analysis with InVEST output
Revealed preference methods

• Use observed behavior to deduce ecosystem service value from a *surrogate* market
  
  – **Hedonic pricing method (Land market)**
    • Influence of environmental/ecosystem attributes on property value
  
  – **Travel cost method (Tourism market)**
    • Costs of recreational visits as proxy of economic use values associated with ecosystems or sites
Hedonic pricing

Land/property price = \textit{function} (attribute_1, attribute_2,...)

- Estimate marginal contribution of each attribute to property value
Hedonic pricing

Land/property price = \textit{function} (attribute1, attribute2, ...)

- Estimate marginal contribution of each attribute to property value

- Aesthetic View
- Water quality
- Recreation
- Species habitat
- Regulating services
- Road
- City
- zoning
Potential valuation extension to InVEST

Linking Upstream Land Use to Near Lake Property Values in Michigan, US

- Water quality of inland lakes
- Average home value for Census Blocks

Average:
- Household income
- Distance to roads
- Number of bedrooms
- Year built
- Ownership
Potential valuation extension to InVEST

Linking Upstream Land Use to Near Lake Property Values in Michigan, US

Potential outputs:

• Total or average property value in a site for current scenarios

• Change of value in future scenarios
Travel cost

• Costs of recreational visits as proxy of economic use values associated with ecosystems or sites

• Visitation rate = Site Features + Visitor Features + Travel Cost + ...

InVEST Recreation Model (% visitor-day) ?

InVEST outputs:
Water quality
Aesthetic view
...

Visitors’ value of recreation site (can be compared to conservation cost)
Stated-preference methods

• Use reported choices to estimate value in a hypothetical market

  – **Contingent valuation**
    Ask respondents to express their willingness to pay (WTP) or willingness to accept (WTA) compensation for changes in ecosystem services

  – **Choice modeling**
    Ask respondents to rank/rate/choose alternative choice sets which have different combination of price attribute and ecosystem attributes
Stated-preference example

- Survey on willingness to pay for ecosystem benefits from land conservation programs

Change in land cover and land use

Change in nutrient & sediment retention

Change in carbon sequestration

Change in habitat quality

InVEST models
Benefit Transfer

• With resource or time constraints, analysis using local data may be impossible

• Benefits transfer uses existing studies to estimate value elsewhere
  – Value transfer
  – Function transfer

• Benefits transfer may not be accurate due to spatial variability
  – Biophysical attributes (climate, quality, size...)
  – Socio-economic attributes (management, disturbance...)
Pros and cons of economic valuation

• Pros
  – Built on economic theory
  – Yields estimates in common (monetary) metric
  – Powerful method to communicate value

• Cons
  – Some values are difficult to measure e.g. spiritual value
  – Valuation can be incomplete, biased and uncertain

• InVEST provides rapid and conservative estimates
  – Best used to compare tradeoffs of alternative scenarios
  – Validated value estimates better for absolute magnitude
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Cost Benefit Analysis

CBA/BCA
• Assess the merits of a policy or action
• Scenario driven, need a baseline
• Who is decision maker?

Standard approach

\[ \sum Benefits \ vs. \ \sum Costs \]

Benefits > Cost, Benefits < Cost

Multiple scenarios

\[ NB_2 > NB_1 > NB_4 > NB_3 \]
Cost Benefit Analysis

CBA/BCA

• General considerations
  – Time horizon
    • Discount rate = time preference
  – Include direct and indirect benefits/costs
    • Same units
    • Relevant stakeholders
  – Risk and uncertainty
  – Iterative process/optimization
  – Scenario design for hypotheses
CBA Dow Example

**Local Forcings**
- Sea level rise
- Storms
- Coastal Development

**Scenarios**
- No restoration (status quo)
- No restoration, build levees
- Restoration
  - Opportunistic
  - Targeted

**Actions**

**Affected Parties**
- Dow
- Public

**Valuation**
- Value of avoided Dow damages
- Action Costs to Dow
- Value of avoided damages
- Value of co-benefits

**Cost Benefit Analysis**
- Net value of management options to Dow and Public
Cost Benefit Analysis

• Pros
  – Yes/no answers on net policy effect
  – Quantitative comparisons

• Caution
  – Full accounting?
    • Indirect effects
    • Monetizing biases to financial/easy-to-measure
  – Distributional effects
    • Are heterogeneous preferences included?
    • Winners compensate losers?
Thanks!

NatCap:
Steve Polasky
Emily McKenzie
Marc Conte
Erik Nelson
The Net Present Value (NPV) of an ecosystem service is the present value of the expected net benefit flows over time.

\[ NPV = \sum_{i=0}^{T-1} \frac{Benefit_i - cost_i}{(1+r)^i} \]

**Number of years** present landscape conditions are expected to persist, or total years the service is valued for.

**Discount rate** (0%~100%): Weight of present benefits versus future benefits
Larger \( r \) \( \rightarrow \) more weight on present
Ecosystem Services and human well-being

Distribution and Change of:
- Welfare
- Cultural importance
- Poverty
- Food security
- Health/nutrition
- Jobs/employment
- Vulnerability metrics

Measures of benefits:
- Monetization
- Other values

Institutions
(Gov’t, Organizations)

Ecosystems

Choices

Institutions
(Property Rights)

Benefits

Nutrition
Crop yields
Water quantity
Shelter
Psychological
Spiritual

Providers
(supply)

Beneficiaries
(demand)

Services

InVEST
The Natural Capital Approach

**DECISIONS**

- Ecosystem structure
- Ecological function

**Supply**
- Potential available
- Location + activity of beneficiaries

**Service**
- Delivered to people

**Value**
- Economic & social impacts
- Social preference
Optimal provision of ES

- Optimal provision is achieved by maximizing social welfare (net benefit = total benefit - total cost)

![Graph showing the relationship between price, total benefit, total cost, and quantity. The graph illustrates the point of maximized social welfare at Q* where the total benefit curve intersects the total cost curve.]
Optimal provision of ES

- Marginal benefit = marginal cost
- Supply = Demand

Maximized Social welfare
Figure 1. Distinctions and Complementarities Among Tools

BSR report