TOOLS FOR MODELING ECOSYSTEM SERVICES

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Pretoria
October 2019
Fundamental questions for modeling services flows

- Where are the ecosystems?
- Where are the beneficiaries?
- How do benefits move from ecosystems to beneficiaries?
- What is the quantity and value of the service?
Spatial context of service flows

Fisher et al. 2009
Spatial context of service flows (cont.)

- Provisioning region
- Non-rival use region
- Rival use region
- Area of critical ES flow
- Blocked flow
- Sink region
- Depleted flows

Spatial context of service flows (cont.)
Types of service flows

Hydrologic services

- Recreation
- Flood regulation
- Coastal protection

Aesthetic viewsheds

- Recreation
- Aesthetic

Carbon sequestration, some cultural values

Recreation, flood regulation, coastal protection

Recreation, aesthetic proximity, some cultural services
Tools for measuring, modelling, and valuing ecosystem services

Guidance for Key Biodiversity Areas, natural World Heritage sites, and protected areas

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WHAT ARE ECOSYSTEM SERVICES?

- Ecosystem processes and functions
  - e.g. primary production

- Ecosystem services
  - e.g. wild collected plants

- Benefits/Goods
  - e.g. food

- Human well-being
  - e.g. social, economic and health aspects

Adapted from Haines-Young and Potschin (2010)
WHICH TOOL TO USE?

ECOSYSTEM SERVICES TOOLKIT

WaterWorld

InVEST: integrated valuation of ecosystem services and tradeoffs

Co$ting Nature

ARIES: Artificial Intelligence for Ecosystem Services

The Protected Areas Benefits Assessment Tool

SoLVES: Social Values for Ecosystem Services

mimes
PROTECTED AREA BENEFITS ASSESSMENT TOOL (PA-BAT)

http://wwf.panda.org/our_work/biodiversity/protected_areas/arguments_for_protection/

**The Protected Areas Benefits Assessment Tool**

- Free (PDF guide)
- Stakeholder workshop required for each site
- No computer modeling / GIS required
- Non-spatial
- Qualitative
- Site scale
- Adaptable

Ecosystem Services:
(Any)
Examples include:
- Subsistence fisheries
- Fuelwood
- Harvested wild goods
- Hunting
- Livestock grazing
- Medicinal resources
- Traditional agriculture
- Timber
- Water
- Carbon storage
- Coastal protection
- Flood protection
- Cultural or historical values
- Mental & physical health
- Peace & stability
- Research / knowledge
- Education
- Recreation
- Spiritual values
- Scenic quality
- Wilderness and iconic values
EXAMPLE

Economic benefits from 58 PAs in the Dinaric Arc region

Question: What are the major economic benefits from protected areas?

Why PA-BAT?

Site-level assessment tool, no data required, relatively rapid, workshop-based, no modeling/GIS required

Constraints: Not practical to apply to multiple sites simultaneously, requires workshop(s) for every site, local knowledge may be limited or biased
TESSA: TOOLKIT FOR ECOSYSTEM SERVICE SITE-BASED ASSESSMENT

http://tessa.tools/

- Free (PDF guide)
- Minimal expertise required
- Moderate time required
- Requires field data collection

- Non-spatial
- Quantitative
- Monetary
- Site scale
- Comparative

Ecosystem Services:
1. Global climate regulation
2. Harvested wild goods
3. Cultivated goods
4. Water (provision, quality)
5. Nature-based recreation
6. Cultural (forthcoming)
7. Pollination (forthcoming)
8. Coastal protection (forthcoming)
Economic valuation of Moeyungyi Wetland

**Question:** What is the value of ecosystem services provided by a KBA, and how would the value change under an alternative scenario?

**Why TESSA?**

Site-level assessment tool, comparative, provides results in monetary terms, relatively rapid, no ES expertise required

**Constraints:** Not practical to apply to multiple sites simultaneously, or at the national scale
CO$TING NATURE & WATERWORLD

http://www.policysupport.org/costingnature
http://www.policysupport.org/waterworld

- Free (basic) or paid (advanced)
- No expertise required
- Least time required
- No data required

- Spatial
- Quantitative
- Non-monetary
- Site to global scale
- Scenarios

Ecosystem Services:
1. Carbon
2. Freshwater (quantity, quality, flow regulation)
3. Hazard mitigation
4. Nature tourism
EXAMPLE

Regional-scale analysis of freshwater services provided by PAs

Question: what is the total contribution of PAs to freshwater services in Amazonia?

Why WaterWorld? Rapid, all required data provided

Constraints: not open-source, uncertainty related to accuracy of global data
INVEST: INTEGRATED VALUATION OF ECOSYSTEM SERVICES AND TRADEOFFS

www.naturalcapitalproject.org/invest/

- Free
- Open-source
- Requires a GIS
- Moderate time required
- Requires data (for example, land cover)
- Spatial (maps)
- Quantitative
- Non-monetary or monetary
- Multiple scales (local to national)
- Comparative (scenarios)

Ecosystem Services:
1. Carbon
2. Coastal blue carbon
3. Coastal vulnerability
4. Fisheries
5. Habitat quality
6. Habitat risk assessment
7. Marine fish aquaculture
8. Marine water quality
9. Nearshore waves and erosion
10. Offshore wind energy
11. Recreation
12. Water yield (hydropower production)
13. Scenic quality
14. Sediment retention
15. Water purification
16. Wave energy
EXAMPLE

National scale ecosystem service modeling

Question: How are KBAs benefitting people in Myanmar at a national scale?

Why InVEST?

National-scale, relatively low data requirements

Constraints: modeling based on limited data & assumptions, requires GIS expertise
ARTIFICIAL INTELLIGENCE FOR ECOSYSTEM SERVICES (ARIES)

http://aries.integratedmodelling.org/

- Free (k.LAB software) & open-source
- Currently: specialized expertise / training required
- Future: web-interface (no expertise required)
- New case studies: all data required
- Global models: no data required
- Spatial
- Qualitative or quantitative
- Monetary or non-monetary
- Site to global scale
- Cloud-based
- Collaborative
- Context-specific

Ecosystem Services (global models - can be run development):
run anywhere):
1. Carbon storage
2. Flood regulation
3. Pollination
4. Recreation
5. Sediment regulation

Case studies (cannot be run anywhere):
1. Aesthetics/scenic quality
2. Biodiversity
3. Carbon sequestration
4. Crop production
5. Cultural/spiritual values
6. Fisheries
SOCIAL VALUES FOR ECOSYSTEM SERVICES (SOLVES)

https://solves.cr.usgs.gov/

- Free
- Spatial mapping of social values
- Requires ArcGIS
- Requires social surveys / social science expertise
- Can be used to assess values
- of diverse stakeholder groups
- Quantitative 10-point social values metric
- Values Transfer Tool
- Can be combined with biophysical modeling tools

Ecosystem Services
- Any social or cultural values

Examples include:
- Cultural or historical values
- Cultural heritage
- Inspiration, creative or artistic
- Social relations
- Community benefits
- Research / knowledge benefits

- Recreation, nature tourism
- Scenic quality / aesthetic viewsheds
- Wilderness and iconic values
- Etc.
PAUSE FOR QUESTIONS
## TOOL REVIEW

<table>
<thead>
<tr>
<th>Name</th>
<th>Acronym</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integrated Valuation of Ecosystem Services and Tradeoffs</td>
<td>InVEST</td>
</tr>
<tr>
<td>Toolkit for Ecosystem Service Site-based Assessment</td>
<td>TESSA</td>
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<tr>
<td>Co$ting Nature</td>
<td>C$N</td>
</tr>
<tr>
<td>Artificial Intelligence for Ecosystem Services</td>
<td>ARIES</td>
</tr>
<tr>
<td>Social Values for Ecosystem Services</td>
<td>SoLVES</td>
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<tr>
<td>Multiscale Integrated Models of Ecosystem Services</td>
<td>MIMES</td>
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<tr>
<td>Protected Areas Benefits Assessment Tool</td>
<td>PA-BAT</td>
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<tr>
<td>Ecosystem Services Toolkit</td>
<td>EST</td>
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<tr>
<td>WaterWorld</td>
<td>WW</td>
</tr>
</tbody>
</table>
1. Reason for assessment
- Advocacy
- Spatial Planning
- Finance
- Establish a PES scheme

2. Type of outputs needed
- Qualitative / quantitative
- Spatial / non-spatial
- Monetary / non-monetary
- Single site / multi-site

3. Practical considerations
- Time
- 
- $ 
- Expertise
- Data

InVEST: integrated valuation of ecosystem services and tradeoffs
Co$t
ing: Nature
ARIES: Artificial Intelligence for Ecosystem Services
SoLVES: Social Values for Ecosystem Services
mimes: LUIC
### 1. Reason for assessment

<table>
<thead>
<tr>
<th>Reasons for measuring ES provided by sites</th>
<th>ARIES</th>
<th>C$N</th>
<th>EST</th>
<th>InVEST</th>
<th>MIMES</th>
<th>PA-BAT</th>
<th>SoiVES</th>
<th>TESSA</th>
<th>WW</th>
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</thead>
<tbody>
<tr>
<td><strong>Public/policy support</strong></td>
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<td>Provide additional evidence and justification for the importance of conserving a particular site</td>
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<td>Foster local awareness of the ES provided by a particular site</td>
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<td>Build support for the conservation of multiple sites through increased understanding of their wide range of benefits</td>
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<td>Link ES contributed by all sites in a country to international or national sustainability goals and national policies (e.g., SDGs)</td>
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<td><strong>Site management</strong></td>
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<td>Establish the baseline of ES provided by a site to enable monitoring of changes and support management planning</td>
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<tr>
<td>Reveal synergies and possible trade-offs between ES and/or ES and conservation objectives to identify management options for the site</td>
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<tr>
<td>Develop, implement and update management strategies for the site (e.g., integration of ES into site’s management plan or developing a business plan for the site)</td>
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<td><strong>Human well-being</strong></td>
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<tr>
<td>Ensure a good understanding of the ES values that are important to resident, local and more distant stakeholders</td>
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<td>Assess compensation options to resident and local stakeholders for ES forgone as a result of biodiversity conservation, to contribute to discussions about Free Prior and Informed Consent, conflict resolution, etc.</td>
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</tbody>
</table>

- = can potentially be used; ++ = can potentially be used and there are case studies
TYPES OF OUTPUTS NEEDED & PRACTICAL CONSIDERATIONS

1. Do you need results that are **quantitative**?
2. Do you need results to be spatially explicit (**maps**)?
3. Do you need results that are in **monetary units**?
4. Is the assessment for a **single site** or area?
5. Do you need results which are **comparative** (between two sites or policy scenarios?)
6. Do you have capacity / time to **develop the model** yourself?
7. Do you **already have data** on ecosystem services at the relevant scale?
8. Do you have capacity / time for **field data collection**?
9. Do you have capacity / time for **stakeholder consultation** or surveys?
### 2. Type of outputs needed

<table>
<thead>
<tr>
<th>Tool</th>
<th>ARIES*</th>
<th>C$N</th>
<th>EST</th>
<th>InVEST</th>
<th>MIMES</th>
<th>PA-BAT</th>
<th>SolVES</th>
<th>TESSA</th>
<th>WW</th>
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</thead>
<tbody>
<tr>
<td><strong>Type of outputs that can be produced</strong></td>
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<tr>
<td>Maps of services (GIS based)</td>
<td>✓</td>
<td>✓</td>
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<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>Maps of services (participatory mapping)</td>
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<tr>
<td>Relative or qualitative values</td>
<td>✓</td>
<td>✓</td>
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<td>✓</td>
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<tr>
<td>Quantitative (biophysical units)</td>
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<td>✓</td>
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<tr>
<td>Monetary value</td>
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<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>Designed for scenario comparison</td>
<td>✓</td>
<td>✓</td>
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</tbody>
</table>

| **Time, resources and skills required**  |        |     |     |        |       |        |        |       |    |
| Requires additional paid software licenses | ✓      |     | ✓   | ✓      | ✓     | ✓      | ✓      | ✓     | ✓  |
| Requires use of GIS software             | ✓      |     | ✓   | ✓      | ✓     | ✓      | ✓      | ✓     | ✓  |
| Requires modelling skills                | ✓      |     |     | ✓      | ✓     | ✓      | ✓      | ✓     | ✓  |
| Requires social science knowledge        |        |     | ✓   | ✓      |       |        |        | ✓     | ✓  |
| Online training available for modelling tools | ✓      | ✓   | ✓   | N/A    | ✓     | N/A    | ✓      |       | ✓  |
| User support available                   | ✓      | ✓   | ✓   | ✓      | ✓     | ✓      | ✓      | ✓     | ✓  |

Table 4

### 3. Practical considerations
DECISION TREES

INTRODUCE ES
For users that want to learn more about the ES concept and assessments

ASSESS ES
Identify ES, their condition, importance & trends

MAP ES
Identify the location and spatial extent of an area that provides ES & where beneficiaries are located

ECONOMIC VALUATION of ES
Calculate or estimate monetary value of ES

GUIDANCE DOCUMENT TOOLS
Provides more general information on ES and a range of assessment approaches (see Fig 3a)

Do you have data? (e.g. soil data, population data, DEM)

NO

MAPPING TOOLS
Tools that help the user produce map(s) of where ES are located (see Fig. 3c)

YES

MODELLING TOOLS
Can require more data and be more complex to apply but allow for a wide variety of analysis, such as identifying areas where conservation will benefit most ES or to see which scenarios are most beneficial for ES (see Fig. 3b)

Do you have resources to collect data?

NO

MODELLING TOOLS CONTAINING DATA
Provide a relatively quick and low cost option to assess some ES, but rely on built in global or national data sets which give less accurate results (see Fig. 3b)

YES

DATA COLLECTING TOOLS
Provides guidance and methods on how to collect ES data and thereafter how to assess and evaluate ES (see Fig. 3c)
### WHICH ECOSYSTEM SERVICES DO YOU WANT TO ASSESS?

<table>
<thead>
<tr>
<th>Ecosystem Service</th>
<th>ARIES*</th>
<th>CSN</th>
<th>InVEST</th>
<th>PA-BAT</th>
<th>Solves</th>
<th>TESSA</th>
<th>WW</th>
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</thead>
<tbody>
<tr>
<td><strong>Provisioning</strong></td>
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<tr>
<td>Fisheries / Subsistence fisheries (wild)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>Freshwater aquaculture</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>Fuelwood</td>
<td>✓</td>
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<td>✓</td>
<td>✓</td>
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<td>✓</td>
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<tr>
<td>Genetic material</td>
<td>✓</td>
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<td>✓</td>
<td>✓</td>
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<td>✓</td>
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<tr>
<td>Harvested wild goods / Hunting / Non-wood forest products (e.g. honey, mushrooms, berries)</td>
<td>✓</td>
<td>✓</td>
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<td>✓</td>
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<tr>
<td>Livestock grazing</td>
<td>✓</td>
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<td>✓</td>
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<td>✓</td>
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<tr>
<td>Marine fish aquaculture</td>
<td>✓</td>
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<tr>
<td>Material extraction (e.g. coral, shells, resin, rubber, grass, rattan)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>Medicinal resources</td>
<td>✓</td>
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<tr>
<td>Production / Cultivated goods / Traditional agriculture</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>Timber</td>
<td>✓</td>
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<td>✓</td>
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<td>✓</td>
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<tr>
<td>Water - Water provision / Water supply / Water quantity / Water yield</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td><strong>Regulating</strong></td>
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<tr>
<td>Carbon (sequestration)</td>
<td>✓</td>
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<td>✓</td>
<td>✓</td>
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<td>Carbon (storage) (terrestrial)</td>
<td>✓</td>
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<td>Coastal blue carbon</td>
<td>✓</td>
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<tr>
<td>Coastal protection / Coastal flood regulation / Coastal vulnerability</td>
<td>✓</td>
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<td>Erosion</td>
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<td>Flood protection / Flood regulation / Flood prevention</td>
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<td>Greenhouse gas flux</td>
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<tr>
<td>Landslide risk / Soil stabilisation / Avalanche protection</td>
<td>✓</td>
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<td>Pest &amp; disease regulation</td>
<td>✓</td>
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<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Pollination / Crop pollination</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Sediment retention / Sediment regulation / Sediment delivery / Sediment provision</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Seasonal water yield - regulation of timing</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Water purification / Water quality</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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</tbody>
</table>

Table 5
### WHICH ECOSYSTEM SERVICES DO YOU WANT TO ASSESS?

<table>
<thead>
<tr>
<th>Ecosystem Service</th>
<th>ARIES*</th>
<th>CSN</th>
<th>InVEST</th>
<th>PA-BAT</th>
<th>SoVES</th>
<th>TESSA</th>
<th>WW</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cultural</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cultural and historical values / Cultural heritage / Inspiration, creative or artistic / Social relations/community benefits</td>
<td>✔</td>
<td></td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td></td>
<td>✔</td>
</tr>
<tr>
<td>Health, mental &amp; physical</td>
<td>✔</td>
<td></td>
<td>✔</td>
<td></td>
<td></td>
<td></td>
<td>✔</td>
</tr>
<tr>
<td>Peace &amp; stability</td>
<td></td>
<td></td>
<td></td>
<td>✔</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Research / Knowledge</td>
<td></td>
<td>✔</td>
<td>✔</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Education</td>
<td></td>
<td></td>
<td>✔</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recreation / Nature tourism / Leisure</td>
<td>✔</td>
<td></td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Spiritual values / Sacred natural sites</td>
<td></td>
<td></td>
<td>✔</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sense of place / Identity</td>
<td></td>
<td></td>
<td>✔</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scenic quality / Aesthetic viewsheds</td>
<td>✔</td>
<td></td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td></td>
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<tr>
<td>Wilderness and iconic values [as a cultural value]</td>
<td></td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td></td>
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<tr>
<td><strong>Other benefits that can be modelled/assessed</strong></td>
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<td></td>
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<tr>
<td>Employment</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✔</td>
</tr>
<tr>
<td>Existence / Bequest value</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✔</td>
</tr>
<tr>
<td>Habitat quality / Nature conservation / Biodiversity</td>
<td>✔</td>
<td></td>
<td>✔</td>
<td></td>
<td>✔</td>
<td></td>
<td></td>
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<tr>
<td>Habitat risk assessment</td>
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<td></td>
<td>✔</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Criterion</td>
<td>ARIES</td>
<td>CoSting Nuture</td>
<td>EST</td>
<td>InVEST</td>
<td>MIMES</td>
<td>PA-BAT</td>
<td>SoI/ES</td>
</tr>
<tr>
<td>---------------------------------</td>
<td>------------------------</td>
<td>----------------</td>
<td>----------------------</td>
<td>-----------------------</td>
<td>------------------------</td>
<td>------------------------</td>
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</tr>
<tr>
<td>Cost &amp; open/closed source</td>
<td>Free, open-source</td>
<td>Free (policy analyst or scientist version) or paid license (advanced user or commercial versions), closed-source</td>
<td>Free, open-source</td>
<td>Free, open-source; requires purchase of SIMILE software (closed-source)</td>
<td>Free, open-source</td>
<td>Free, requires purchase of ArcGIS software (closed-source)</td>
<td>Free, open-source</td>
</tr>
<tr>
<td>Availability</td>
<td>Available</td>
<td>Available</td>
<td>Available</td>
<td>Available</td>
<td>Available</td>
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<td>Available</td>
</tr>
<tr>
<td>Time requirements</td>
<td>Low</td>
<td>Low to high</td>
<td>Moderate to high</td>
<td>High for new case studies</td>
<td>Low to moderate</td>
<td>Low to high</td>
<td>Low to high</td>
</tr>
<tr>
<td>Data input demand</td>
<td>Low to high</td>
<td>Low to high</td>
<td>Moderate to high</td>
<td>High</td>
<td>Low</td>
<td>Low to moderate</td>
<td>Moderate to high</td>
</tr>
<tr>
<td>Skill requirements</td>
<td>Low to high</td>
<td>Low to high</td>
<td>Moderate to High</td>
<td>High</td>
<td>Low</td>
<td>Moderate</td>
<td>Low</td>
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<tr>
<td>Scale of analysis</td>
<td>Local to global</td>
<td>Local to global</td>
<td>Local to global</td>
<td>Local to global</td>
<td>Local</td>
<td>Local to regional</td>
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<tr>
<td>Quantitative / Qualitative</td>
<td>Quantitative or Qualitative</td>
<td>Quantitative or Qualitative</td>
<td>Quantitative or Qualitative</td>
<td>Quantitative</td>
<td>Qualitative</td>
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<tr>
<td>Monetary / Nonmonetary</td>
<td>Monetary or nonmonetary</td>
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<td>Monetary or nonmonetary</td>
<td>Monetary or nonmonetary</td>
<td>Nonmonetary</td>
<td>Nonmonetary</td>
<td>Nonmonetary</td>
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<tr>
<td>Spatially explicit</td>
<td>Yes</td>
<td>Yes</td>
<td>Either</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Technical requirements</td>
<td>Computer and internet access</td>
<td>Computer and internet access</td>
<td>None</td>
<td>Computer, GIS software</td>
<td>Computer access, SIMILE software, GIS software</td>
<td>None</td>
<td>Computer, ArcGIS</td>
</tr>
<tr>
<td>User support</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Low</td>
<td>High</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>Level of development &amp; documentation</td>
<td>Case studies &amp; global models developed and documented</td>
<td>Partially documented</td>
<td>Fully developed and documented</td>
<td>Fully developed and documented</td>
<td>Case studies developed and documented</td>
<td>Fully developed and documented</td>
<td>Fully developed and documented</td>
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</table>

Table 6
<table>
<thead>
<tr>
<th>Criterion</th>
<th>ARIES</th>
<th>Co$ting Nature</th>
<th>EST</th>
<th>InVEST</th>
<th>MIMES</th>
<th>PA-BAT</th>
<th>SolIVES</th>
<th>TESSA</th>
<th>WaterWorld</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range of time for full application in a new site (scoping, data collection, analysis follow-up)</td>
<td>Days to weeks for pre-existing models; months to a year for a new case study</td>
<td>Minutes to hours for application of the model with all provided data</td>
<td>Hours to days for scoping process; highly variable for a complete assessment depending on the methods/tools selected, resources/capacity of assessment team, and extent/quality of results expected</td>
<td>1-3 months for smaller projects, less if data exist and scenarios identified upfront; 6 months to 2 years for larger projects with multiple ES, depending on level of stakeholder involvement</td>
<td>3 months to learn model functioning, 1-3 months for smaller projects, 6 months to 2 years for larger projects</td>
<td>1 day workshop, days to weeks for preparation, subsequent analysis of workshop results, follow-up</td>
<td>Months to a year for survey design and gathering survey data; minutes to run the model once survey data are available</td>
<td>20-60 person days for preparation, primary data collection (biophysical and socioeconomic), and analysis</td>
<td>Minutes to hours for application of the model with all provided data</td>
</tr>
</tbody>
</table>

**General summary / insights**

- Spatially explicit ecosystem service trade-offs, flow, and uncertainty maps; currently time consuming for new applications, unless using global models
- Rapid analysis of indexed, bundled services based on global data, along with conservation priority maps
- Detailed step-by-step guide with built-in tools to complete ES assessment including analysis of biophysical, sociocultural, and economic values; compendium of additional tools, methods, and data sources; and guide to using results in multiple policy/decision contexts
- Spatially explicit ecosystem service trade-offs maps; currently relatively time consuming to parameterise
- Dynamic modelling and valuation using input-output analysis; ecosystem trade-off and decision making, highly time consuming to develop
- Qualitative paper-based forms for protected area managers and stakeholders to assess benefits provided by protected areas
- Provides maps of social values for ecosystem services; time consuming for new studies but lower-cost for value transfer
- A collection of site-based comparative assessment methods targeted at practitioners without specialised skills
- Rapid analysis of detailed biophysical assessment based on global data, along with conservation priority maps

*Table 6*
ANNEX II: TOOL DESCRIPTIONS & CASE STUDIES

1. Short description of the tool
2. User requirements (software, data, expertise)
3. Which ecosystem services can be modelled with the tool?
4. Can it be applied in terrestrial, freshwater, and coastal/marine contexts?
5. Strengths or unique features that set it apart from other tools
6. Limitations
7. Potential applications for conservation
8. Case studies
9. Approximate time (staff-days) and cost of a full application of the tool in a new context
Annex II. Description of tools and case studies

A brief description of each tool is provided, including its purpose, application, and limitations. Case studies are included to demonstrate the use of the tools in real-world scenarios. The tools include ARIES, CoVes, and various ecological models. The summary section highlights the main findings and implications of the use of these tools in different contexts.

Artificial Intelligence for Ecosystem Services (ARIES)

Description
ARIES is an AI tool designed to assist in the development of ecosystem service models. It uses machine learning algorithms to analyze and predict ecosystem service flows, providing insights into the impacts of human activities on biodiversity and ecosystem health.

User requirements
ARIES requires users to provide input data on ecosystem services, including spatial and temporal data. The tool is best suited for users with some background in ecology and data analysis.

Case study
ARIES was used to model the impact of land-use changes on the carbon sequestration capacity of a coastal wetland. The results showed significant reductions in carbon sequestration due to changes in land use.

Summary
ARIES is a powerful tool for ecosystem service modeling and can be used to inform policy decisions. However, it is important to consider the limitations of the tool, such as the need for high-quality input data and the potential for oversimplification of complex ecological processes.

ARIES Case Study

Evaluating biocultural and ecological ecosystem service hotspots using ARIES and CoVes to inform national forest planning in the United States

The US Forest Service has conducted a series of studies to evaluate the ecological and cultural importance of national forests. These studies have been conducted in collaboration with local communities and stakeholders.

Time and resources
The project was conducted over a period of about 3 years. The data collection and analysis involved a team of 10 researchers, including ecologists, cultural anthropologists, and geographers.

Stakeholders and collaborators
The project involved partnerships with local communities, non-governmental organizations, and academic institutions. The stakeholders included representatives from the USDA Forest Service, local tribes, and academic institutions.

Summary
This project demonstrates the potential of using ARIES and CoVes to inform national forest planning. The results show that these tools can be used to identify areas of high ecological and cultural importance, which can inform conservation and management decisions.

Beneficiaries
The project beneficiaries include local communities, national forest managers, and researchers interested in ecosystem services. The results can inform decision-making processes related to land-use planning and conservation.

Key results
The results show that ARIES and CoVes can be used to identify key areas for conservation and management. The results can inform decision-making processes related to land-use planning and conservation.

Next steps
The project is ongoing, with plans to expand the analysis to other national forests and to integrate additional data sources, such as climate change projections.
<table>
<thead>
<tr>
<th>Tool Description</th>
<th>Cost</th>
<th>Availability</th>
<th>Open Source (for software)</th>
<th>Generalizability / Applicability in new contexts</th>
<th>Capacity for independent application</th>
<th>Scale of analyses</th>
<th>Applicability to terrestrial, freshwater, marine</th>
<th>Time requirements</th>
<th>Data input demand</th>
<th>Technical requirements</th>
<th>Skill requirements</th>
<th>Interface</th>
<th>Level of stakeholder engagement required</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>WHET</strong></td>
<td>Free</td>
<td>Available</td>
<td>Requires use of MS Excel</td>
<td>Low; currently developed for the US only</td>
<td>Yes, within the U.S.</td>
<td>Single or multiple</td>
<td>Local to regional, terrestrial, freshwater</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Excel spreadsheet (.xls)</td>
<td>Low</td>
</tr>
<tr>
<td><strong>An introductory guide to writing ES</strong></td>
<td>Free</td>
<td>Available</td>
<td></td>
<td>High</td>
<td>Yes</td>
<td>Single or multiple</td>
<td>Local to global</td>
<td>Low</td>
<td>Low</td>
<td>None</td>
<td>Low</td>
<td>PDF guidance document</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>EcoSERVE</strong></td>
<td>Free</td>
<td>Available</td>
<td>Requires use of ArcGIS</td>
<td>UK specific</td>
<td>Yes</td>
<td>Single</td>
<td>Terrestrial and freshwater</td>
<td>High</td>
<td>Medium</td>
<td>ArcGIS with the Spatial Analyst Extension</td>
<td>High</td>
<td>Requires use of ArcGIS</td>
<td>Low</td>
</tr>
<tr>
<td><strong>Ecosystem Services Assessment: how to do one in practice</strong></td>
<td>Free</td>
<td>Available</td>
<td></td>
<td>High</td>
<td>Yes</td>
<td>Single or multiple</td>
<td>Local to global</td>
<td>Low</td>
<td>Low</td>
<td>None</td>
<td>Low</td>
<td>PDF guidance document</td>
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<tr>
<td><strong>Ecosystem Services Assessment Support Tool</strong></td>
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<td>Available</td>
<td></td>
<td>High</td>
<td>Yes</td>
<td>Single or multiple</td>
<td>Local to global</td>
<td>Low</td>
<td>Low</td>
<td>None</td>
<td>Low</td>
<td>Online guidance</td>
<td>None</td>
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<tr>
<td><strong>Ecosystem services identification and inventory tool</strong></td>
<td>Free for version one</td>
<td>Available</td>
<td>Closed source</td>
<td>High</td>
<td>Yes</td>
<td>Single</td>
<td>All (but not tested in marine environments)</td>
<td>Medium</td>
<td>High</td>
<td>High (field data collection)</td>
<td>Low</td>
<td>Web-based or an app</td>
<td>Low</td>
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<tr>
<td><strong>Ecosystem Services Partnership Visualization Tool (ESPVVT)</strong></td>
<td>Free</td>
<td>Yes</td>
<td>N/A</td>
<td>N/A</td>
<td>Yes</td>
<td>N/A</td>
<td>Local to national</td>
<td>Low</td>
<td>Low</td>
<td>None</td>
<td>Low</td>
<td>Website</td>
<td>None</td>
</tr>
<tr>
<td><strong>Ecosystem services Valuation Toolkit (EVT)</strong></td>
<td>Not available currently</td>
<td>Available</td>
<td>At present, EVT is an internal tool for access by Earth Economics team members only</td>
<td>Low</td>
<td>No</td>
<td>N/A</td>
<td>All (in the state of California)</td>
<td>Low</td>
<td>Low</td>
<td>None</td>
<td>Low</td>
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<td>All</td>
<td>Low</td>
<td>Low</td>
<td>None (included in the tool)</td>
<td>Low</td>
<td>Website</td>
<td>Low</td>
</tr>
</tbody>
</table>
Tools for measuring, modelling, and valuing ecosystem services

Guidance for Key Biodiversity Areas, natural World Heritage sites, and protected areas


Craig Groves, Series Editor

https://portals.iucn.org/library/node/47778

Rachel Neugarten
rneugarten@conservation.org
ARIES framework

**Smart technology:** specifically developed for mapping and quantifying of ecosystem services, requires minimal training

**Utilizes existing ecological-process models:** those commonly used or previously published

**Builds ad hoc probabilistic models:** with an expert input, accounts for uncertainty, handles missing data

**Machine learning:** capable of deriving relationships from the data

**Artificial intelligence:** used for model selection

**Capable to model service flow:** agent-based approach accounts for spatial and temporal dynamics of service flows
ARIES Explorer

https://www.youtube.com/watch?v=vsWGkMBpl9Y

- displaying spatial data (0-7 mins)
- mapping ecosystem services (7-15 mins)
- spatial scenarios analysis (15-17 mins)
- importing your own data and models (17-20 mins)
Example of using the ARIES explorer in Madagascar

prepared by Rachel Neugarten
January 2019
Carbon vegetation mass (t/ha)
10,000 km (?) resolution model run time: 4 min
Data flow
Carbon organic mass (soil?); 5,000 km², run time <8 min
Net value of pollination (5,000 km², run time 15 min)
Net value flood regulation (5,000 km², run time 10 min)
Value of outdoor recreation (5,000 km², run time 10 min)
Region of interest

- C organic mass [t/ha]
- Net value of pollination
- Net value of flood regulation
- Flood probability
- Flood regulation demand
- Flood regulation supply
- Value of outdoor recreation
- Demand for recreation
- Theoretical value of outdoor recreation
- Potential value of outdoor recreation

Grid size:
350598 (426 x 823) cells

Cell size:
0.02 x 0.018

Total area
Sediment retention (5,000 km², run time 10 min)
THANK YOU!