Quantification, Modelling and Valuing of Ecosystem Services: Some thoughts on the perspectives of the concept.

Ralf Seppelt, Carsten Dormann, Florian Eppink, Sven Lautenbach
2010, Kiel, Salzau
Solutions for Sustaining Natural Capital and Ecosystem Services
What are we actually talking about?
Filter capacity of a beech tree equals the work of 20 charwoman.
A beech is producing 12 kg sugar a day, 1680 kg in a summer, for which two Barka pick-up trucks are needed for transport.
Ecosystem Services: The Beech...

...supports climate regulation by producing the daily mount of oxygen required for 13 people
…which could also be used for burning 4 l petrol, needed for driving 50km with a Trabant car.
Resource Management

- The global ecosystems provides us with a limited, but renewable resources.
- Increasing human population size, economic growth and consumption patterns are continuously putting pressure on environmental systems.

Haberl, 2007
Millennium Ecosystem Assessment

- Provision of food, fuel and fibre
- Provision of shelter and building materials
- Purification of air and water
- Detoxification and decomposition of wastes
- Stabilization/moderation of the Earth's climate
- Moderation of floods, droughts, temperature extremes and the forces of wind
- Generation and renewal of soil fertility
- Pollination of plants
- Control of pests and diseases
- Maintenance of genetic resources as key inputs to crop varieties and livestock breeds, medicines, and other products
- Cultural and aesthetic benefits
- Ability to adapt to change
Does the ecosystem service concept support management of human appropriation of natures goods and services?
§1 “Natur und Landschaft sind […] als Grundlage für Leben und Gesundheit […] im besiedelten und unbesiedelten Bereich […] zu schützen, dass

1. die biologische Vielfalt,

2. die Leistungs- und Funktionsfähigkeit des Naturhaushalts einschließlich der Regenerationsfähigkeit und nachhaltigen Nutzungsfähigkeit der Naturgüter sowie

3. die Vielfalt, Eigenart und Schönheit sowie der Erholungswert von Natur und Landschaft auf Dauer gesichert sind […]”
Two Contrasting Concepts?

- Biodiversity Approach
  - Land purchase
  - Easement purchase
  - Focus on species and habitats

- Ecosystem service Approach
  - Service goals
  - Consider human well-being

Methods
- Case study of The Nature Conservancy Projects (TNC)
- Semi-structured interviews
- Database (34 ES projects, 26 BD projects)
- US, Central, South America

Goldman et al. 2008 PNAS
Results

- Ecosystem service projects address the same threats
Results

- Ecosystem service projects address the same threats
- Ecosystem service projects engage new stakeholders

Goldman et al. 2008 PNAS
Results

- Ecosystem service projects address the same threats
- Ecosystem service projects engage new stakeholders
- Ecosystem service projects use a greater variety of finance tools
Yes, we can!

Can we?
Review on Ecosystem Services

Indicators & Criteria
- Data source
- Indicator used
- System border Definition
- Considered uncertainty
- Number of ecosystem services
- Ecosystem services in isolation
- Model type
- Monetarisation
- Scenario-Analysis
- Specific recommendation given
- Stakeholder involvement
- Results validated

Search in web of science:
- ‘ecosystem service’,
- ‘ecosystem services’ or
- ‘ecosystem valuation’ in the title
More than 450 studies 20 years
Brief Results

- wide variety of approaches
- lack of consistent methodology
- frequent use proxy variables
- observations or measurements (< 40%)
- secondary data (>60%)
- models based assessments (<25%)
- without considering any feedbacks (>50%)
- scenarios (30%)
Location of ESS studies per country
4 facets of Ecosystem Service Assessments

- ensure **biophysical realism** of ecosystem indicators and models;

- consideration of local **trade-offs**

- consider **off-site effects**

- comprehensive but critical involvement of **stakeholders**
Biophysical realism

1. provide best data and knowledge, independent of the methodology used in further steps of the assessment
2. consider interacting ecosystem functions / processes
3. selection of the appropriate complexity of the models or indicators
4. test of assessment for robustness and reliability
Biophysical realism: Some Examples

Eigenbrod et al. 2010

Schrödter et al. 2005


MIMES, Bourmans, pers. comm

Biological Regulation
Trade offs

- Ecosystem service trade offs
  - can be temporal
  - can be spatial
  - affect economic production

1. Investigated how new policies will affect ecological (static)
2. the causality underlying ecological processes is understood (dynamic)
3. Ecosystem service assessments should uncover how ecosystems are likely to respond to change in human activities
Trade offs: Examples

- Trade off curve for two benefits:
  - Species conservation: terrestrial vertebrates
  - Market returns: commodities and value of rural residential housing development

- Which landscape patterns maximize joint production?
- Explore full scenario space

Polasky, et al. 2008

Holzkämper & Seppelt, 2005
Off site effects

- Local ecosystem services linked to services that are provided globally
- Human-induced effect: international trade in goods can imply a trade in ecological damage

1. Developing methods to study off site effects, as ecosystem processes are coupled at small as well as large spatial scales
   - Ecological Footprint (EF)
   - Water Footprint (WF)
Stakeholder Involvements

- Stakeholder help identify which ecosystem services are relevant
- Stakeholders provide a ground-truthing for the development of management options
- Stakeholders evaluate possible management options, either by ranking them or by assigning weights of importance to different services
Stakeholder Involvements

1. Stakeholder involvement should hence be seen as a method
   - to gain a wider picture,
   - to ground-truth academic possibilities and
   - to provide a first estimate of which measures of ecosystem management would be looked upon favourably by members of the public

2. confront stakeholders with the impact of their preferences
Yes we can, if...
Yes, we can, if…

…we avoid the using “ecosystem services” for selling our good science.
…help make the concept robust and reliable
…we carefully quality check our work with respect to these 4 facets
…follow a consistent and widely accepted documentation blueprint
Integrated qualification: Modelling and valuing of ecosystem services

Workshop Objectives

Ralf Seppelt, 2010, Kiel, Salzau
Solutions for Sustaining Natural Capital and Ecosystem Services
Integrated quantification, modelling and valuing of ecosystem services.

Sounds like a theory of almost everything, esp. those question one never dared to ask…
Workshop: Content

Presentations
- Concepts
- Methods
- Case Studies

- Short presentations
- 10 Minutes + 10 Minutes Discussions
- Keep Sequence, allowing people to move around
- Keep a core group to discussed core questions
Workshop: Core Questions

Derive guidelines/criteria
- for using and applying indicators and
- models of appropriate complexity
- that are capable of a robust valuation of ecosystem services
- and that as suitable for assessing quality of life/human well being.
Workshop: Core Questions (1)

Case studies on Ecosystem Services research and applications....

- How can we cope with the variability, heterogeneity?
- How can be compare, transfer, generalize with respect to
  - methodology,
  - Indicators
  - Models
  - Valuations
Workshop: Core Questions (2)

Case studies on Ecosystem Services research and applications…

- How can we test results
  - with respect to underlying data, monitoring, secondary data…
  - with respect to assessments
  - with respect to stakeholder work
Workshop: Core Questions (3)

Case studies on Ecosystem Services research and applications...

- How can be embed results in global assessments based on
  - drivers on global changes, global scenarios
  - Local results, impacts
  - Possible off-site effects
What’s next?

- Short presentations
  - 10 Minutes + 10 Minutes Discussions
  - Keep Sequence, allowing people to move around

- Discussion-Slots
  - Tue: 16:30 – 18:00
  - Wed: 14:00 – 17:30
  - Thu: 10:30 – 11:30

- Products
  - Anything welcome

- Some of you had a long journey to come
- Use it for interaction, discussions, create ideas
- … this is why we are here!
Workshop: Core Questions (4)

Case studies on Ecosystem Services research and applications…

- Anything forgotten?
- Anything to add?
Blueprint...

Critical questions for ecosystem service assessments with respect to the art of biophysical realism
Has the model been tested or validated in this system for these indicators? How significant is uncertainty? How robust are the results in the face of uncertainty?

...Trade offs:
Which correlations between ecosystem services were independently shown to be causal by literature and or measurements/field work? Will these be the same trade offs under different scenarios/management solutions or in changing environments? Were secondary effects of changes in the supply of ecosystem services on the economic structure considered?

...Off-site effects
Were environmental processes on larger temporal and spatial scales considered? Were trade mediated effects on larger spatial scale considered? Were differences of local and off-site valuation of ecosystem service changes considered?

...stakeholder work
Were the results and statements derived from stakeholder selection and stakeholder work tested or validated, e.g. does it match observed behaviour? Were the composition answers and transparent?
Fazit

- Schutz- und Management Konzepte basierend auf ESS sind sinnvoll und können erfolgreich und effizient sein.
- Schutzkonzepte können nur Erfolg haben, wenn die auch die Art der Bewirtschaftung der umliegenden Flächen berücksichtigt wird.

Acknowledgements
Bernd Gruber
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Sven Lautenbach
…
Critical questions for ecosystem service assessments with respect to the art of biophysical realism

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Were the composition answers and transparent?
Impact assessment: Biophysical Models

(Schröter et al., 2005, Science)
## Impact Assessment

<table>
<thead>
<tr>
<th>Sector</th>
<th>Model</th>
<th>Reference</th>
</tr>
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<tbody>
<tr>
<td>Agriculture</td>
<td>Land use change scenario</td>
<td>(Rounsevell et al. 2006)</td>
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<td></td>
<td>SUNDIAL</td>
<td>(Smith et al. 1996)</td>
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<td></td>
<td>ROTHC</td>
<td>(Coleman and Jenkinson 1996, Coleman et al. 1997)</td>
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<td></td>
<td>IMAGE (biofuel demand)</td>
<td>(IMAGE team 2001)</td>
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<td>Forestry</td>
<td>GOTILWA+</td>
<td>(Sabaté et al. 2002)</td>
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<td>EFISCEN</td>
<td>(Nabuurs et al. 2000, Karjalainen et al. 2002)</td>
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<tr>
<td>Carbon storage</td>
<td>LPJ (biogeochemistry)</td>
<td>(Sitch et al. 2003, fire dynamics: Thonicke et al. 2001)</td>
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<td>Conservation</td>
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<tr>
<td>Mountains</td>
<td>RHESSys (mountains)</td>
<td>(Band et al., 1993, Tague and Band 2001, Tague and Band, 2004)</td>
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Mapping
INVEST

- Integrated Valuation of Ecosystem Services and Tradeoffs tool
- Spatially explicit modeling tool
  - Multiple services
  - Ecological production functions
  - Economic valuation techniques
- Inputs:
  - Land use / land cover map, future scenarios
  - Data tables, GIS layers
- Outputs:
  - Biophysical production and economic value
  - Maps, trends, balance sheets, tradeoff analyses

http://www.naturalcapitalproject.org/toolbox.html
Services implemented (Tier 1)

- Carbon sequestration
- Water quality
- Storm peak mitigation
- Soil conservation
- Biodiversity
- Market returns to landowners
Further Examples

- How big a payment is needed for landowner to switch from current land use to conservation?
- “Opportunity costs” of conservation

- Plot full tradeoff curve for two benefits:
  - Species conservation: terrestrial vertebrates
  - Market returns: commodities and value of rural residential housing development
- Which landscape patterns maximize joint production?
- Explore full scenario space

Methodology

- Concept: Tier 1 to 3 models with increasing complexity
  - Tier 1: **mapping, indicators**, no intercations/interdependencies of ecosystem functions, services
  - Tier 2, 3: biophysical realism is supposed to increase

- ARCGIS based nicely configured front end, applicable within stakeholder meetings
Assessment using data based models

Red-Backed Shrike
Middle Spotted Woodpecker
Wood Lark

Leipzig, Germany

\[
hsi(x, y) = \frac{\exp\left(d_0 + \sum_{k=1}^{n} d_k p_{hab}(x, y)\right)}{1 + \exp\left(d_0 + \sum_{k=1}^{n} d_k p_{hab}(x, y)\right)}
\]
Modelling, dynamic
MIMES Objectives / Goals

- Multi-scale Integrated Models of Ecosystem Services
- Develop a sophisticated and transferable system to elucidate dynamics of ecosystem services.
  - Develop a dynamic spatial model
  - Collect data
  - Provide a user interface
- Understand the link between ecosystem services and human welfare
- Develop valuation protocols
- Forecast changes in ecosystem functions and values under various management scenarios.
- Model scenario development
Expected Outcome

- Outcome 1. a suite of dynamic ecological economic computer models specifically aimed at integrating our understanding of ecosystem functioning, ecosystem services, and human well-being across a range of spatial scales.

- Outcome 2. developed and applied new valuation techniques adapted to the public goods nature of most ecosystem services and integrated with the modeling work.
Methodology / Summary

- Modular concept
- Generic conceptual model for different applications
- Dynamics introduced by ordinary differential equations
- Spatially explicitly on grid or polygon structure
- Using SIMILE Environment (www.simulistics.com)
Ecosystem Service (index)

- Climate Regulation
- Biological Regulation
- Natural Hazard Mitigation
- Cultural Heritage
- Genetic Information
- Inorganic Resources

Boumans, 2009, pers. comm.
Summary

Policy change → Impacts on ecosystem → Changes in ecosystem services → Impacts on human welfare → Economic value of changes in ecosystem services

(DEFRA, 2007)

MIMES

INVEST

HELMHOLTZ CENTRE FOR ENVIRONMENTAL RESEARCH – UFZ
Application: Managing Biodiversity

Leipzig, Germany

**Task:** optimise land use patterns for maximum habitat performance with contrasting species habitat requirements

\[
hsi(x, y) = \frac{\exp\left(d_0 + \sum_{k=1}^{n} d_k p_{hab}(x, y)\right)}{1 + \exp\left(d_0 + \sum_{k=1}^{n} d_k p_{hab}(x, y)\right)}
\]

(Holzkämper, EcoMod, 2004)
Announcement: The GLUES Project (2009-2014)

GLUES: Global Assessment of Land Use Dynamics on Greenhouse Gas Emissions and Ecosystem Services

- Analysis of regional Projects on land use management and Ecosystem Services
- Global consistent Scenarios
...For the entire biosphere, the value (most of which is outside the market) is estimated to be in the range of US$16–54 trillion per year.

Costanza et al. (Nature, 1997)

Cost in action for climate mitigation and adaption: 1% of global GDP
Cost for no action: 5% of global GDP
30. Oktober 2006

Pavan Sukhdev calculated the price for environmental damage and loss of biodiversity in consequence of deforestation is at between $2 trillion and $5 trillion per year. This is a lot more than the cost of the current financial crisis which economists gauge at about $1.5 trillion.

www.spiegel.de, 10 Oktober 2009