Assessment of strengths & weaknesses of biophysical models for ecosystem accounting

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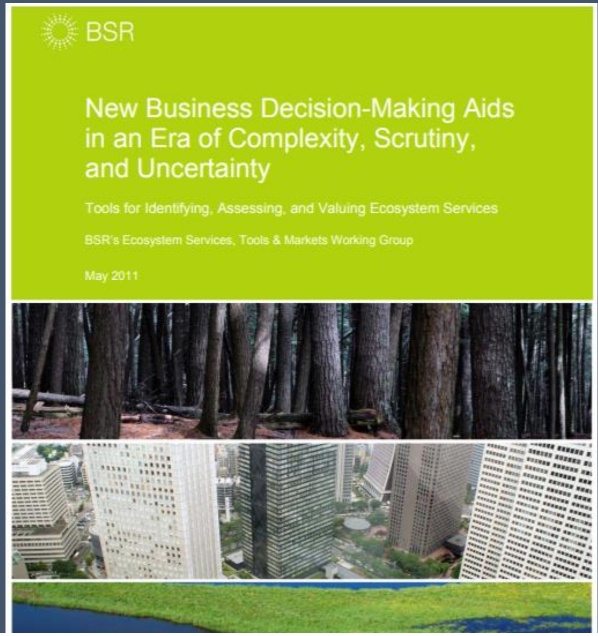
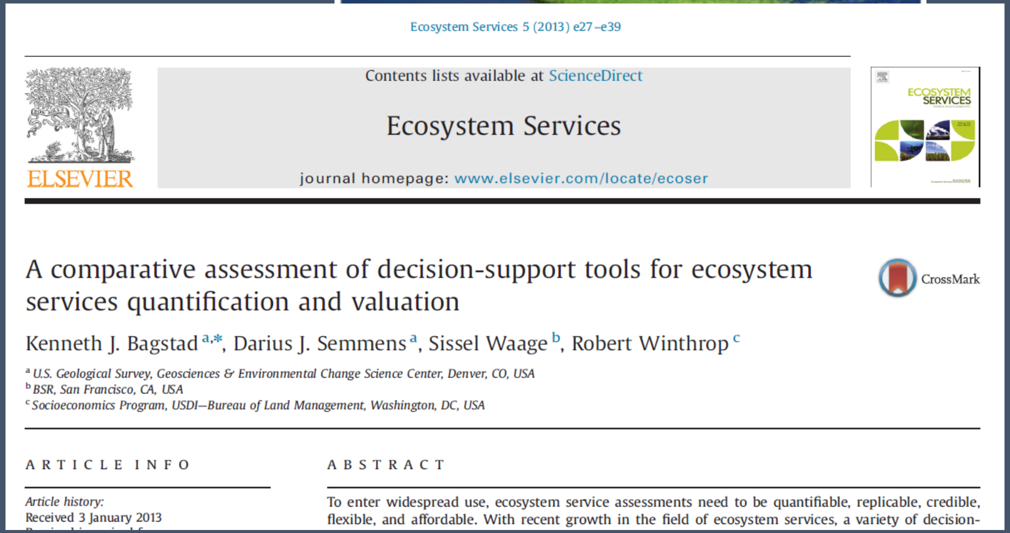
science for a changing world

1st review of ecosystem services tools (2010-2011)

- Lots of tools, needed comparison /w evaluative criteria
  1. Uncertainty quantification
  2. Time requirements
  3. Ability to apply independently
  4. Development & documentation
  5. Scalability
  6. Generalizability
  7. Nonmonetary/cultural perspectives
  8. Cost effectiveness





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A comparative assessment of decision-support tools for ecosystem services quantification and valuation

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ABSTRACT

To enter widespread use, ecosystem service assessments need to be quantifiable, replicable, credible, flexible, and affordable. With recent growth in the field of ecosystem services, a variety of decision-

MANY subsequent ES tool/model reviews

- 2015: ValuES project (web guide to ES tools)
- 2016: Christin et al. (ES for IUCN/forest restoration), Healy & Secchi (ES & wetland restoration)
- 2017: Gret-Regamey et al. (ES decision support tools), Harrison et al. (decision tree approach), Palomo et al. (book chapter in Maes & Burkhard)
- 2018: Chaplin-Kramer et al. (ES tools for World Bank), Ding & Bullock (ES assessment in Sub-Saharan Africa), IPBES Policy Support Portal, Neugarten et al. (ES for KBAs & protected areas)

On one hand, how many more of these do we need?
(typically evaluate similar tools with similar findings)

If you can use them to understand the key needs of different communities, they could be valuable (what are ours, for ecosystem accounting?)

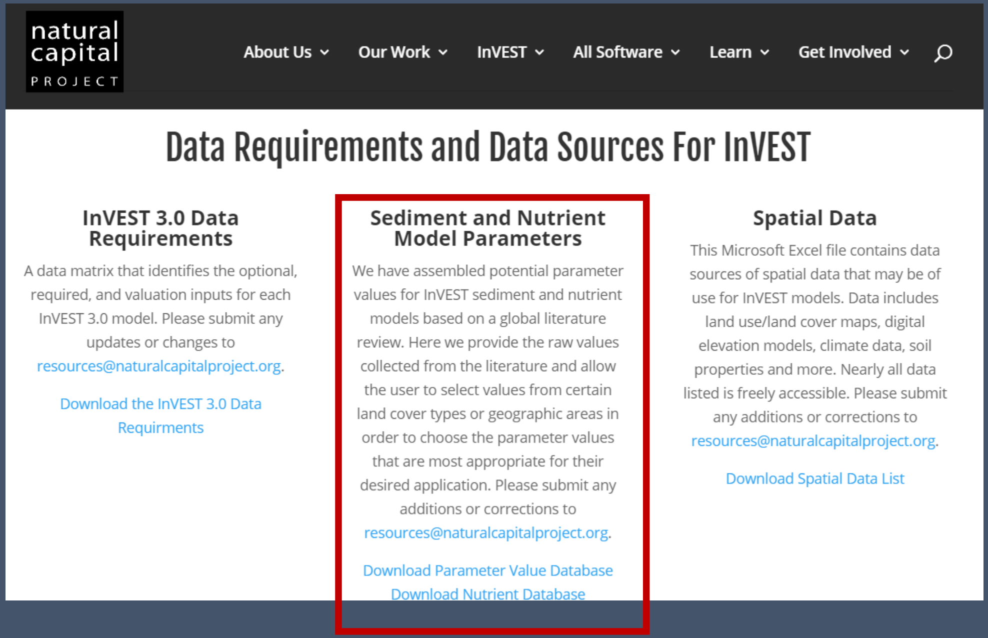
Time requirements of ecosystem service modeling

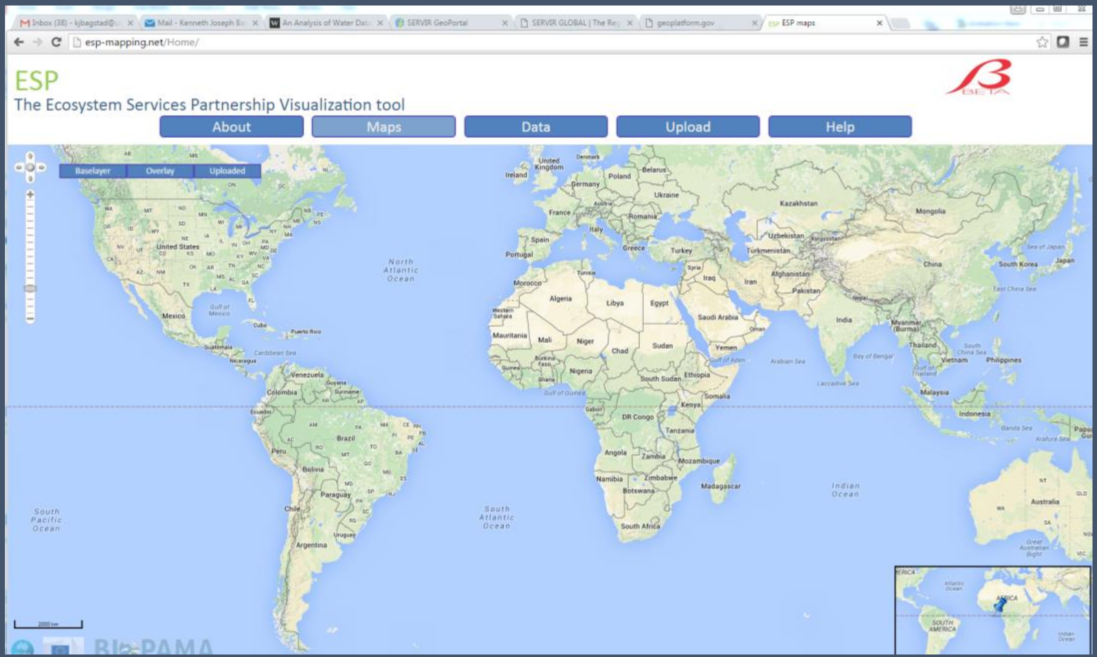
Case study	Tool	# ecosystem services	Time requirements (months)*
San Pedro River, AZ, USA	ARIES, InVEST	4	16
Puget Sound, WA, USA	ARIES	5	18
CO-WY Rocky Mountains, USA	ARIES, SolVES	4, plus cultural ES	16
West Maui, HI, USA	ARIES	2	18
Cape Lookout National Seashore, NC, USA	SolVES, custom models	4, plus cultural ES	16
Yahagi watershed, Japan	ARIES	2	6
Rwanda	InVEST	4	18

*From start to completion of modeling, excluding time to publish
Also excludes time for training local government staff in modeling

A lack of data & model sharing greatly inhibits our progress

- We reinvent the wheel, repeatedly
- Sharing data & models on the cloud could make ES assessments much faster, flexible, more accurate (interoperability)
- We'd use the best available knowledge, not be bound to a particular modeling framework
- The technology is there to do it
- BUT we lack incentives/culture of data sharing (open data movement is slowly changing this)





www.esp-mapping.net

Potentially important recent developments in ES modeling tools

- ARIES: global/customizeable models now available (Martinez-Lopez et al. in review); long-planned web interface for models coming within ca. next 6 months
    - Way to make data & models interoperable, bring in case specific information like the InVEST parameter databases
- Co$ting Nature 3.0: includes 12 different ES models (up from 6 in version 2.0)
- InVEST: global model runs for multiple ES completed (Kim et al. in review)

How to make sure models aren’t “misused?”: An initial proposal

- I.e., overly simple models presented/used as authoritative?

★ Baseline global models with global data

★★ Half of data inputs & parameters reviewed/replaced with local data/values

★★★ 90% or more of data inputs & parameters reviewed/replaced with local data/values

★★★★ Sensitivity analysis & successful model calibration completed

- Don’t use a 1-star model for a 4-star (important) decision

Studies comparing different modeling methods & data

- Bagstad et al. 2018 reviewed 19 previous studies + quantitative study for Rwanda
- InVEST & WaSSI models, local vs. global data, high vs. moderate resolution
- Differences emerged, but very little difference in high- vs. low-ES subwatersheds
- Start with Tables 1 & 3 for literature review & expected effects of data & model choices!

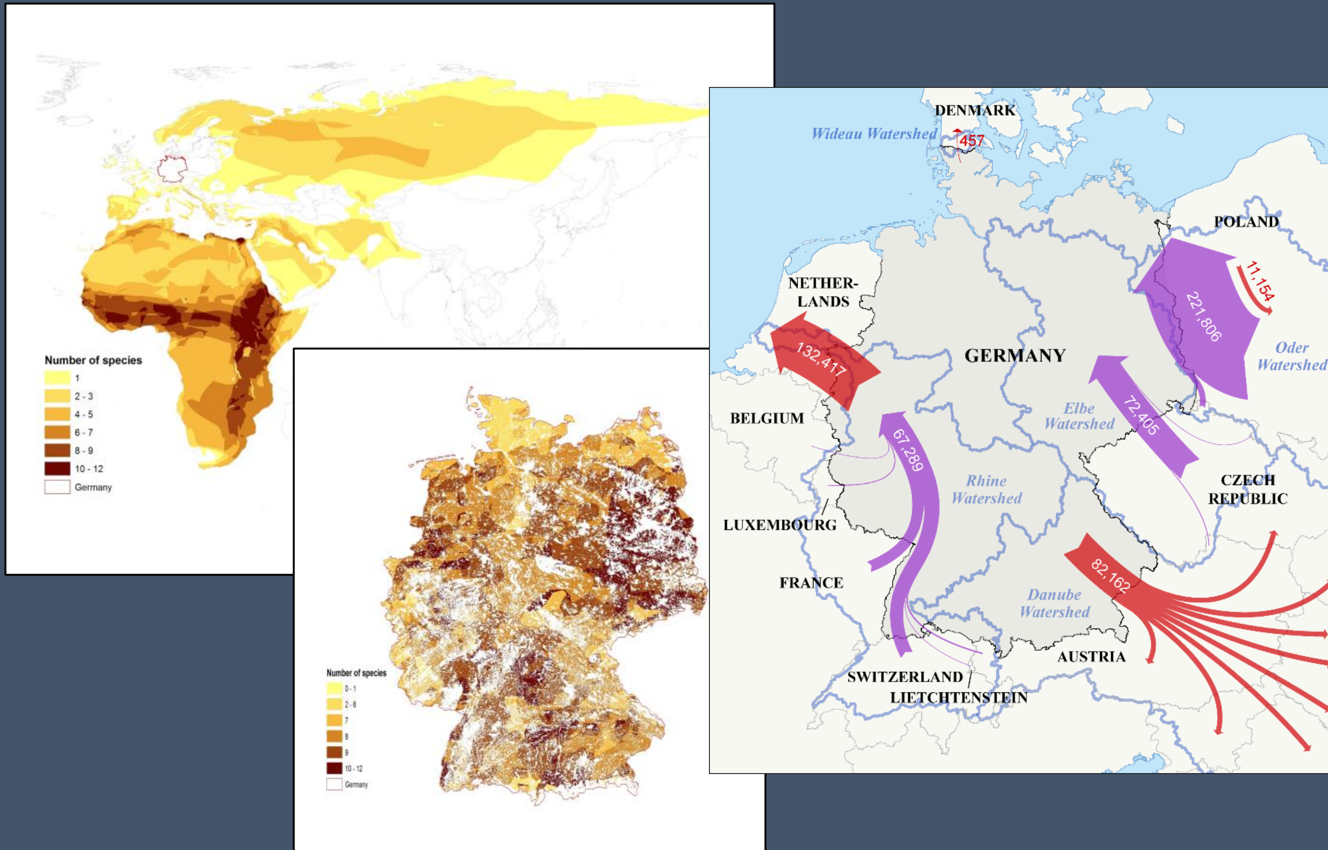
Category	Key findings	Implications for modelers
Model comparison (InVEST-WaSSI annual water yield)	• Both models compared favorably to measured streamflow and MODIS AET data • Both models identified similar temporal trends • Model results were highly correlated at subwatershed scale • Key differences emerged in total national & provincial scale water yield	• Both models performed adequately in a relatively data-limited context • Model ensembles may be beneficial
Spatial resolution comparison	• Significantly greater water yield (using seasonal water yield model) and less sediment export at coarser scale • Scale differences were significant for carbon models and WaSSI dry-season water yield for one but not both data sources • No scale differences for annual water yield models • Model results were highly correlated at subwatershed scale	• Consider decision context: fine-resolution analysis is needed for spatial prioritization and payments for ecosystem services, but may not be needed for larger-scale screening studies • Consider the heterogeneity of your context (especially topography and land cover); use finer-resolution analysis in heterogeneous environments • Coarser resolution analysis may be more acceptable for simpler models (e.g., InVEST carbon & annual water yield) than complex models (e.g., InVEST seasonal water yield & sediment delivery ratio) • Coarser resolution analysis may be more acceptable for subwatershed-based models (e.g., WaSSI) than pixel-based models (e.g., InVEST)
Input data comparison	• InVEST carbon and sediment models produced different results across all three input datasets; magnitude of difference was greatest for the sediment model • InVEST annual and seasonal water yield and WaSSI models produced similar results for at least two input datasets • Model results were highly correlated at subwatershed scale	• Consider decision context: global data may be acceptable for screening-level analyses where subnational-scale inaccuracies are not important, or for multinational analyses where common data are needed • Spatial pattern, classification accuracy, and thematic resolution can help determine whether global data are acceptable • Quick assessments of spatial pattern and classification accuracy can be done by comparing data to aerial photos or satellite data • High thematic resolution may be beneficial in data-rich environments, which may enable parameterization of many land cover classes, but less valuable in data-limited contexts

Bagstad, K.J., et al. 2018. Applied Geography 93:25-36.

Considering ES imports/exports

- Schröter et al. 2018. Ecosystem Services 31B:231-241.
- Kleeman et al. in prep: Quantitative example for Germany (ES imports/exports)

Sending system	Cocoa flow (tons)	Cropland flow (hectares)	Embedded pollination service (hectares)	Biodiversity impact (species disappearing in the respective ecoregions)
Ivory Coast	123,939	238,607	5,388,525	0.38
Ghana	62,280	179,170	3,404,221	0.45
Nigeria	43,397	161,739	3,073,036	0.96
Cameroon	39,031	111,995	2,127,906	3.39
Togo	27,172	43,345	823,564	0.24
Ecuador	14,936	26,702	507,336	1.88
Indonesia	13,476	29,285	556,415	0.22
Other countries	24,395	95,476	1,814,037	1.25
Total flows to Germany	348,626	931,318	17,695,037	8.78



What criteria might be important for ecosystem accounting community? If we're not getting there, why not?

Ability to run in data-scarce regions

Ability to use/integrate multiple model types

Common interface (vs. *ad hoc* models/different programming languages)

Promote data sharing & reuse (interoperability)

Fully customizable (model inputs, parametrization, structure)

Adequate spatiotemporal resolution (may involve HPC in large countries)

Interfaces powerful enough for technical modelers, easy enough for decision makers

Easy to update (as new data become available to extend the time series)

Easy to teach & learn (intuitive; good docs & training materials) – yet accommodate greater complexity if desired

Open-source

Transparent assumptions

Inexpensive to free (acknowledging need for sustainable funding)

Strategy for ecosystem accounting in the U.S.

i.e., a large, heterogeneous, data-rich nation

1. Don’t rely on “kindness of strangers”: tempting, but not replicable over time
2. Collaborative coding (initially in GitHub; aim to transfer to ARIES)
   - Allows others to reuse & contribute code (would love to have international collaboration!)
   - Single location where a user can re-run models as updated data become available (i.e., extend the time series)
3. *Context-awareness* for models: Models need to be parameterized differently in different parts of the country (reflecting key ecological & socioeconomic differences)
4. Ability to link to high-performance computing (HPC) – high-resolution (30 m) model runs over 8.1 million km^2 for multiple years (7 years from 2001 to 2016)

What matters most to us? Can we work as a community to promote, use, & support approaches that achieve our goals?

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The tool development question

- A tool that could quickly, reliably, cheaply track ecosystem services & progress toward the SDGs is a public good (we nearly always underinvest in public goods)
  - Funding for tool development itself, beyond an initial grant, is very hard to find
  - New tools come and go – does not promote stability/emergence of new ideas
- To prevent lock-in to less powerful approaches, need 1) consensus on desired tool characteristics, 2) funding/decision approaches that don’t just follow today’s inertia (community-based process)
- Will we be in the same place in 5 years? 10 years? (ES are hard to measure, and nearly impossible to economically value) Could we get someplace better, more quickly, with strategic investment?