Valuation tools for ecosystem services assessment across spatial and temporal scales

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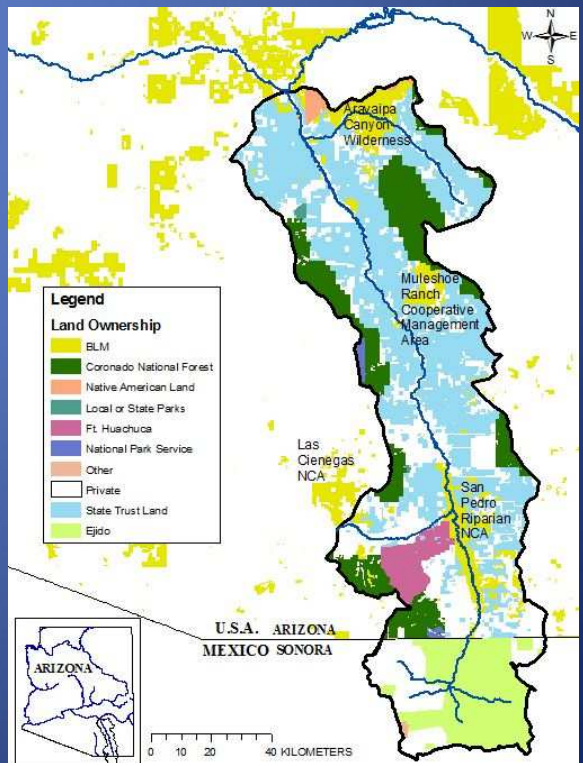
Project Goals

- Determine usefulness of ecosystem service valuation for the BLM
- Determine the feasibility of valuation tools and methods given BLM's capabilities
- Provide relevant information for project planning in the Gila District

Study area & ecosystem services

- San Pedro River, SE Arizona/San Pedro Riparian NCA
- Water, biodiversity, carbon, recreation, "cultural services"



Ecosystem services tools: the landscape

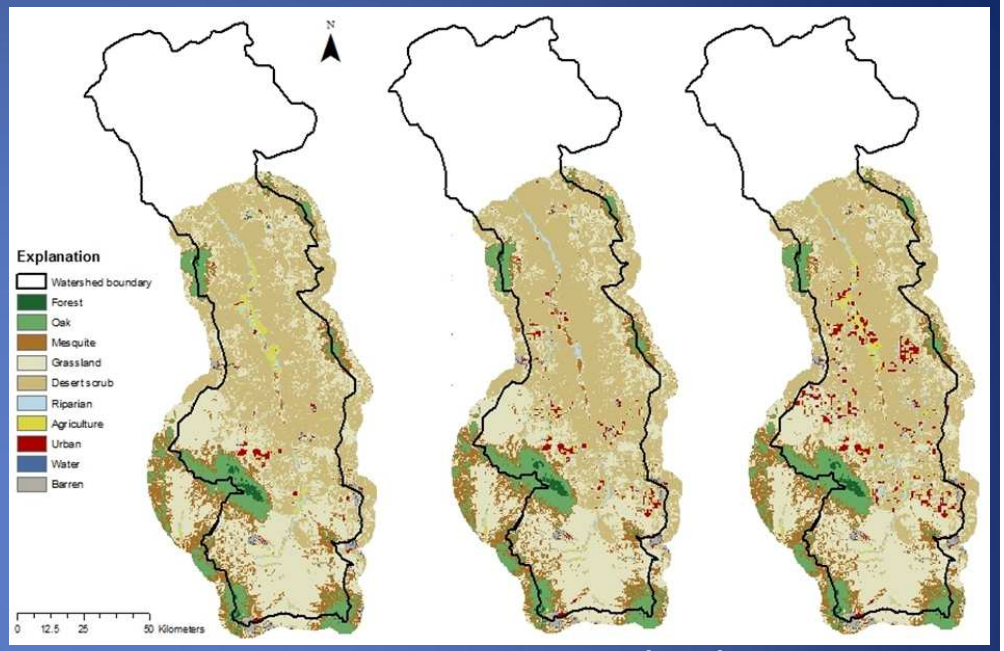
Traditional valuation methods Primary valuation Point transfer Function transfer (multiple regression) Function transfer (Bayesian) Function transfer (Wildlife Habitat Benefits Estimation Toolkit)	**Spatially explicit models, generalizable** ARIES InVEST MIMES SolVES EcoServ LUCI
Proprietary/consultant-driven EcoAIM EcoMetrix ESValue NAIS SERVES	**Spatially explicit models, place-specific** Envision EPM InFOREST
Qualitative tools ESR EVI	UNEP-WCMC Ecosystem Services Toolkit

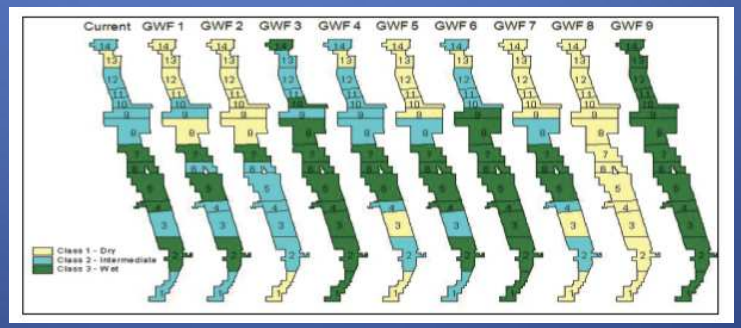
Evaluative criteria: quantification, replication, credibility, flexibility, cost-effectiveness

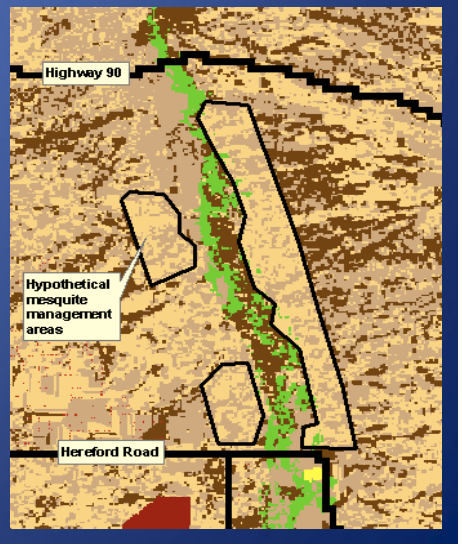
1. Is the tool quantitative, and can it explicitly account for uncertainty?
2. Time requirements?
3. Open source: requirements for hiring consultants vs. using trained staff internally?
4. Current level of development & documentation?
5. Scalability & generalizability?
6. Ability to incorporate multiple cultural & valuation perspectives (i.e., monetary & nonmonetary, Native American/tribal values)?
7. Ability to “mesh” with existing environmental assessment methods, cost-effectively providing new insights

Scenarios

- Urban growth (Steinitz et al. 2003)
- Mesquite management/ grassland restoration
- CAP water augmentation (Brookshire et al. 2010)

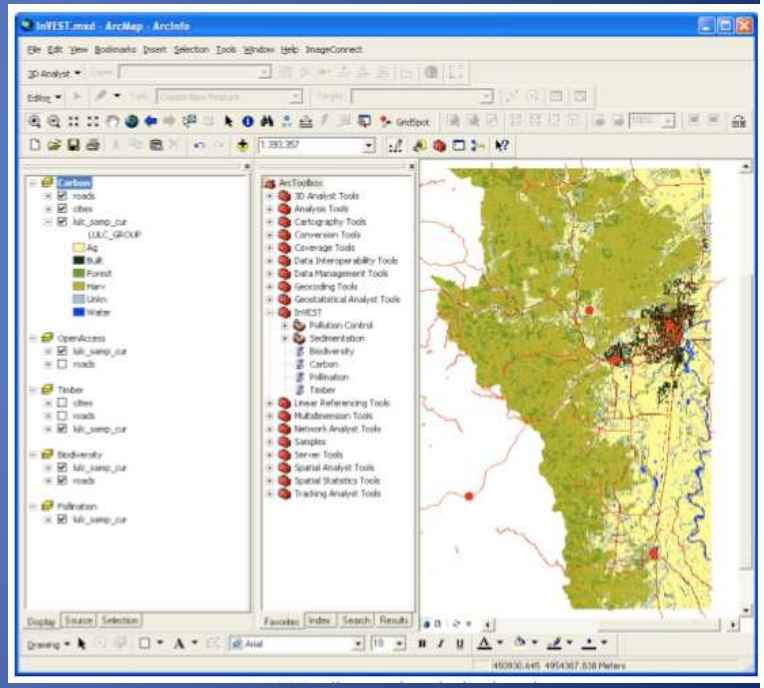






Natural Capital Project/InVEST tool

- Publicly available in beta release at http://www.naturalcapitalproject.org
- Run in ArcGIS 9/10 toolbox or stand-alone
- Designed to run present-day conditions & scenarios via LULC change maps generated by experts or public input
- “Tier 2” models described by Kareiva et al. (2011) but not yet available for download and use



The Nature Conservancy
Protecting nature. Preserving life.

WWF

Woods Institute for the Environment
Stanford University

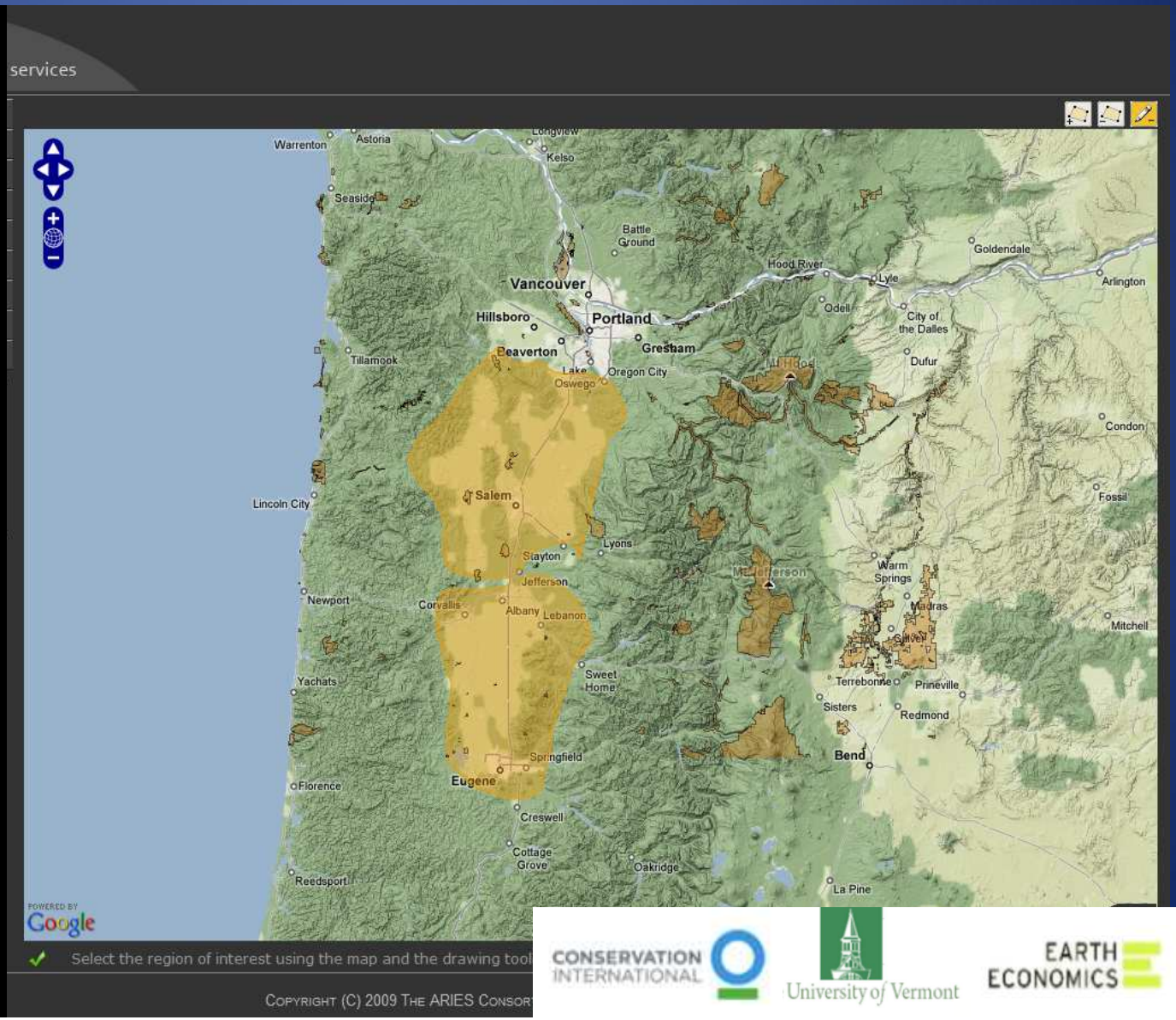
ARIES: A web-based ES analysis tool

Interface through **web browser/software development tool (www.ariesonline.org)**

Probabilistic models carry & report uncertainty estimates, work in regions with incomplete data

Accounts for **spatial flows of ecosystem services** from provision to beneficiaries

Modeling system designed to interface with existing ecological process models



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EARTH ECONOMICS

Methods used

Service	Biophysical modeling & mapping (InVEST & ARIES)	Market price	Social cost	RC	TC	WTP	WTP (transferred)	Hedonic (transferred)
Carbon	✓	✓	✓					
Water	✓	✓		✓			✓	
Biodiversity	✓						✓	
Aesthetics	✓							✓
Recreation	✓				✓	✓	✓	

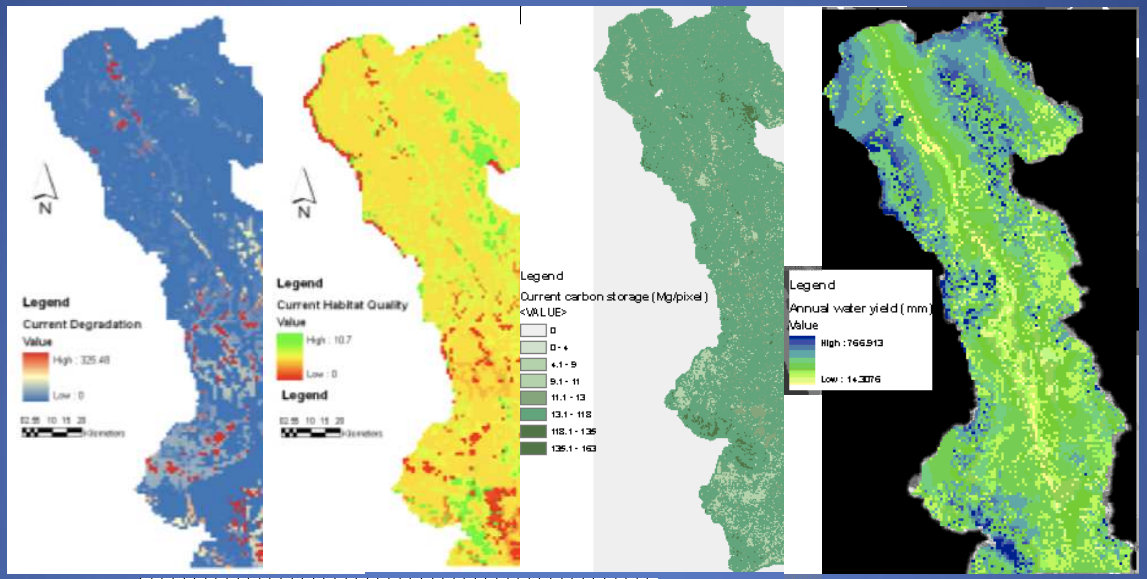
Performance against evaluative criteria (Bagstad et al. 2013a)

Table 2
Description of all ecosystem service tools against key evaluative criteria.

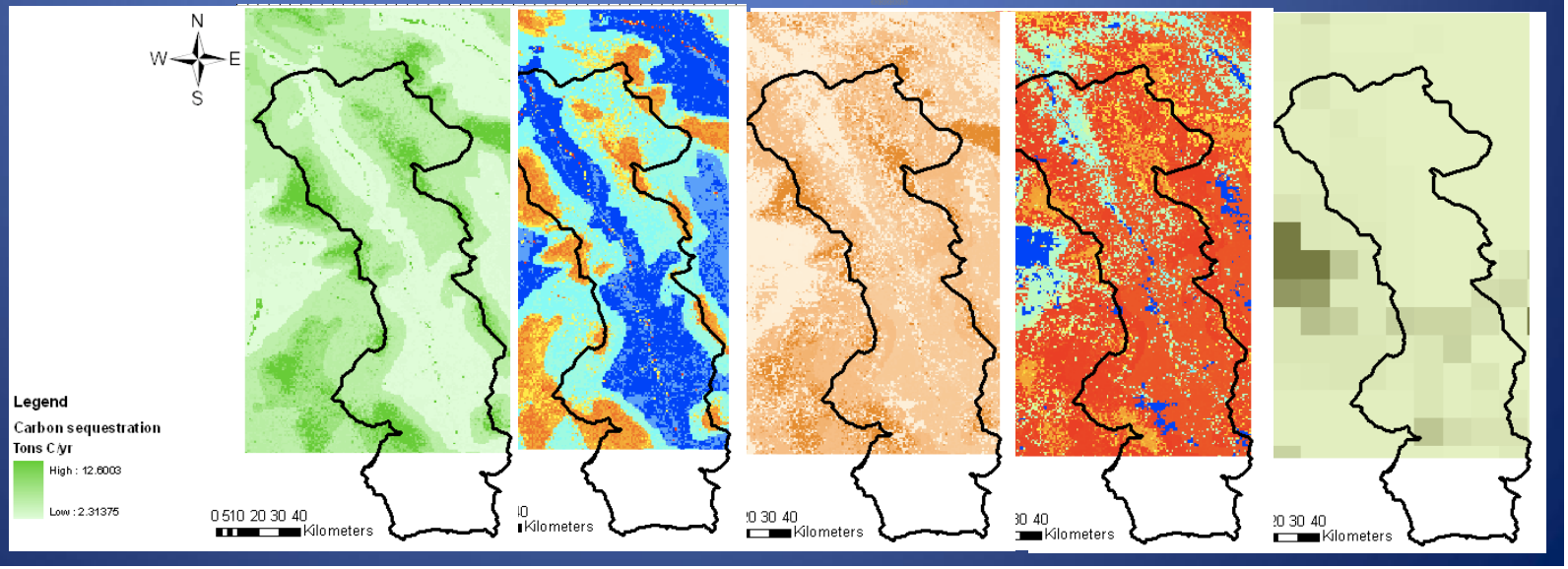
Tool	Quantifiable, approach to uncertainty	Time requirements	Capacity for independent application	Level of development & documentation	Scalability	Generalizability	Nonmonetary & cultural perspectives	Affordability, insights, integration with existing environmental assessment
ESR	Qualitative	Low, depending on stakeholder involvement in the survey process	Yes	Fully developed and documented	Multiple scales	High	No valuation component	Most useful as a low-cost screening tool
InVEST	Quantitative, uncertainty through varying inputs	Moderate to high, depending on data availability to support modeling	Yes	"Tier 1" models fully developed and documented; "Tier 2" documented but not yet released	Watershed or landscape scale	High, though limited by availability of underlying data	Biophysical values, can be monetized	Spatially explicit ecosystem service tradeoff maps; currently relatively time consuming to parameterize
ARIES	Quantitative, uncertainty through Bayesian networks and Monte Carlo simulation	High to develop new case studies, low for preexisting case studies	Yes, through web explorer or stand-alone software tool	Fully documented; case studies complete but global models and web tool under development	Watershed or landscape scale	Low until global models are completed	Biophysical values, can be monetized	Spatially explicit ecosystem service tradeoff, flow, and uncertainty maps; currently time consuming for new applications
LUCI	Quantitative, currently does not report uncertainty	Moderate; tool is designed for simplicity and transparency, ideally with stakeholder engagement	Yes, though website is under development and more detailed user guidance is presumably forthcoming	Initial documentation and case study complete; follow-up case studies in development	Site to watershed or landscape scale	Relatively high; a stakeholder engagement process is intended to aid in "localizing" the data and models	Currently illustrates tradeoffs between services but does not include valuation	Spatially explicit ecosystem service tradeoff maps; designed to be relatively intuitive to use and interpret
MIMES	Quantitative, uncertainty through	High to develop and apply new case studies	Yes, assuming user has access to SIMILE modeling software	Some models complete but not documented	Multiple scales	Low until global or national models are completed	Monetary valuation via input-output	Dynamic modeling and valuation using input-output

Results: ARIES & InVEST models

InVEST biodiversity, carbon, water yield results



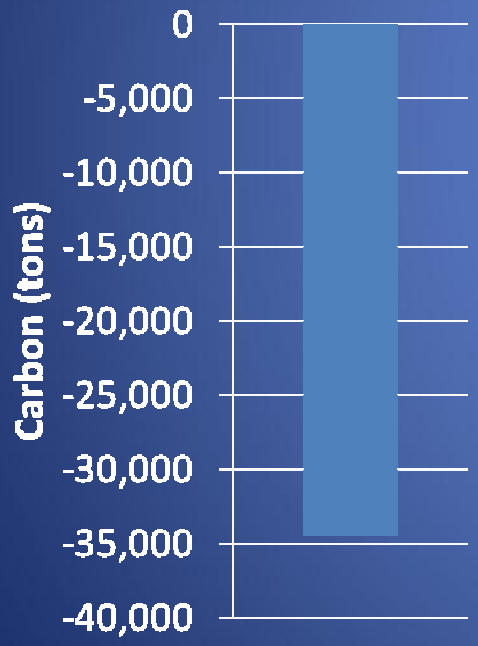
ARIES carbon results, incl. uncertainty maps



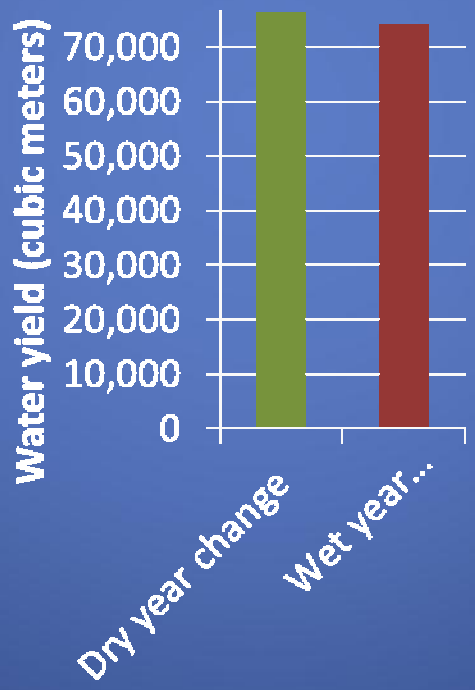
Scenario results: Mesquite management

InVEST

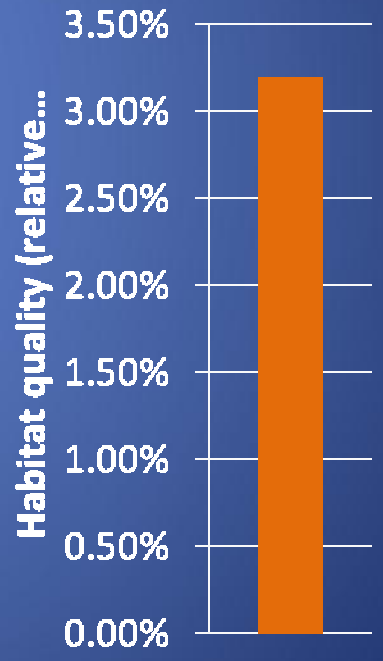
Change in carbon storage



Change in water yield



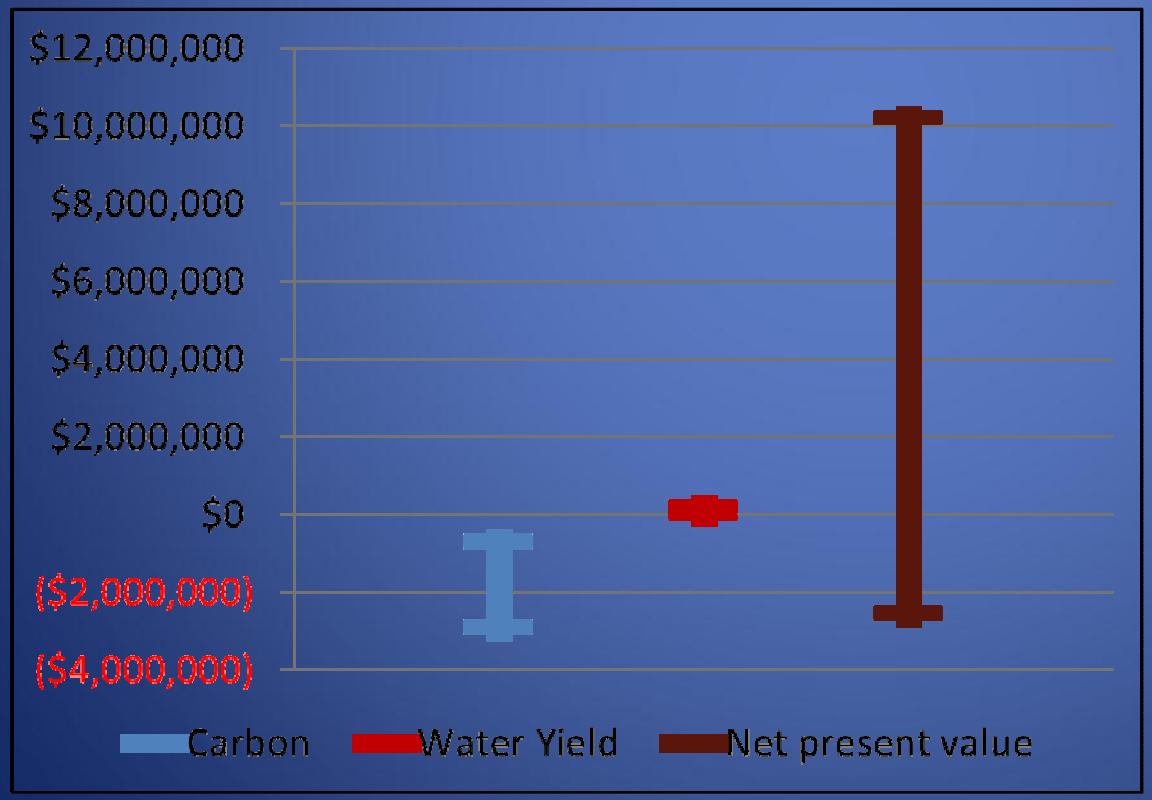
Change in habitat quality



Scenario results: Mesquite management

InVEST (Monetization)

Range of values for carbon, annual water yield, and combined net present value (NPV)



Monetary values depend on assumed price

Service	Cost range
Carbon (ton)	$21 to $85
Water yield (m^3 / year)	$0.33 to $2.32
Discount rate	1% to 7%

Comparability of results (ARIES-InVEST, Bagstad et al. 2013b)

Table 5
InVEST and ARIES results: urban growth.

Service	2020 open change (%)	2020 constrained change (%)
Carbon sequestration (tonnes C/year, InVEST)	−167,950 (−6.3%)	−110,100 (−4.2%)
Carbon sequestration (tonnes C/year, ARIES)	−115,300 (−21.9%)	−109,600 (−20.8%)
Water yield (1000 m^3 water, dry year; InVEST)	+60,842 (12.0%)	+25,910 (5.1%)
Water yield (1000 m^3 water, wet year; InVEST)	+76,096 (7.7%)	+36,391 (3.7%)
Theoretical surface-water sink (1000 m^3 water; ARIES)	−6231 (−2.7%)	−5340 (−2.3%)
Viewshed (million developed pixels visible; InVEST)	+2032.1 (274.9%)	+657.8 (89.0%)
Viewshed theoretical source (relative values; ARIES)	−1000 (−0.1%)	−400 (−0.04%)
Viewshed actual use (relative values; ARIES)	+788,800 (554.7%)	+341,700 (240.3%)

Importance of testing multiple tools in common contexts – understand replicability & where performance diverges

Table 6
InVEST and ARIES results: mesquite management.

Service	Change (%)
Carbon sequestration (tonnes C/year; InVEST)	−1700 (−2.2%)
Carbon sequestration (tonnes C/year; ARIES)	−148 (−1.1%)
Water yield (m^3 water, dry year; InVEST)	+76,000 (0.8%)
Water yield (m^3 water, wet year; InVEST)	+74,000 (0.3%)
Theoretical surface-water sink (m^3 water; ARIES)	−16,000 (−0.3%)

Conclusions: challenges

- Neither model produce reliable, high-quality outputs using reasonable resource levels to use on a Bureau-wide scale
  - Both models require very detailed data to support ecological and economic sub-models
  - Generalized models do not easily reflect local conditions
- Previously collected ecological & economic data do not always integrate well with model data needs

Conclusions: good news

- The process works, but it requires substantial resources and time
- ARIES and InVEST results led us to similar conclusions, especially for landscape-scale scenarios
- Given the rapidly changing landscape for ES tools, the models may rapidly improve development even in the short to medium-term
- Significant opportunities exist to reduce resource requirements to run these models (i.e., data management and sharing)
- Could improve the situation with:
  - Carefully-targeted funding
  - Incentives for collaboration between project teams & government, academic, NGO communities

BLM-wide outcomes

Feasible for immediate agency-wide use	• Ecosystem Services Review, Wildlife Habitat Benefits Estimation Toolkit
Feasible for agency-wide use given development of supporting databases	• Primary Valuation, Point Transfer, Function Transfer, InVEST
Feasible for agency-wide use given pending development of global models or expanded underlying datasets	• ARIES, EcoServ, SolVES
Proprietary tools, feasible for use in high-profile cases where contracting with consultants is possible	• EcoAIM, EcoMetrix, ESValue, NAIS, SERVES
Place-specific tools that require extensive developer support	• Ecosystem Portfolio Model, Envision, InFOREST, MIMES

Comparative multi-tool case studies

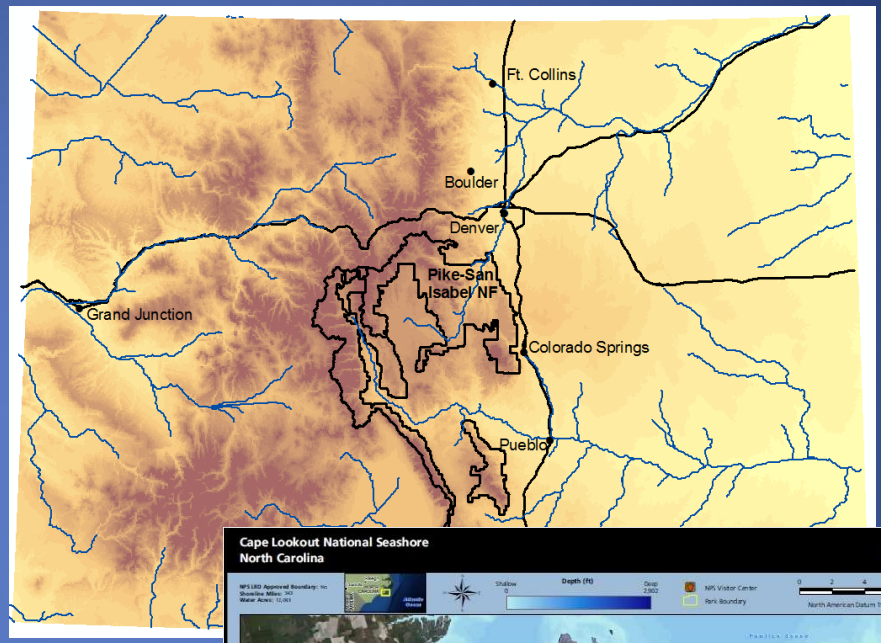
- To our knowledge, San Pedro has been the only one
- Need more:
  - Comparisons between ES-focused tools in the same decision context & with same underlying data (Do we get the same results with different ES tools? When are certain tools more appropriate?)
  - Comparisons between ES tools and disciplinary biophysical models (How well can simplified ES tools perform against more rigorously tested disciplinary models?)

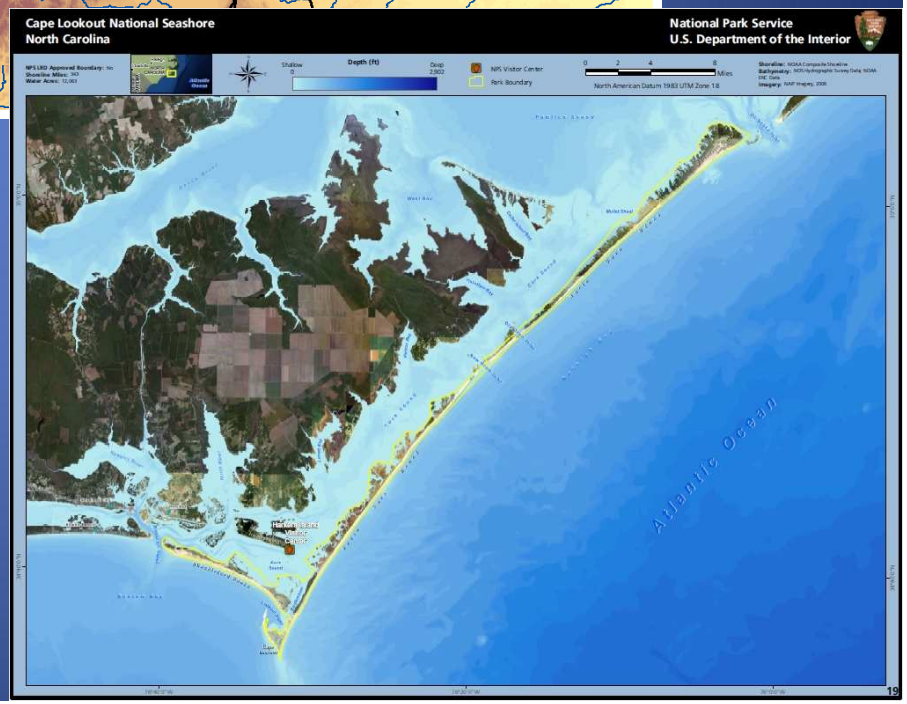
Phase II – Moab, UT

- Bureau of Land Management (BLM)
- Master Leasing Plan
  - Addendum to the existing Resource Management Plan (MLP)
  - 950,000 acres in east-central Utah
  - Oil, gas, and potash development
  - Effect(s) on recreation (aesthetic resources) & freshwater resources

NPS/Forest Service case studies

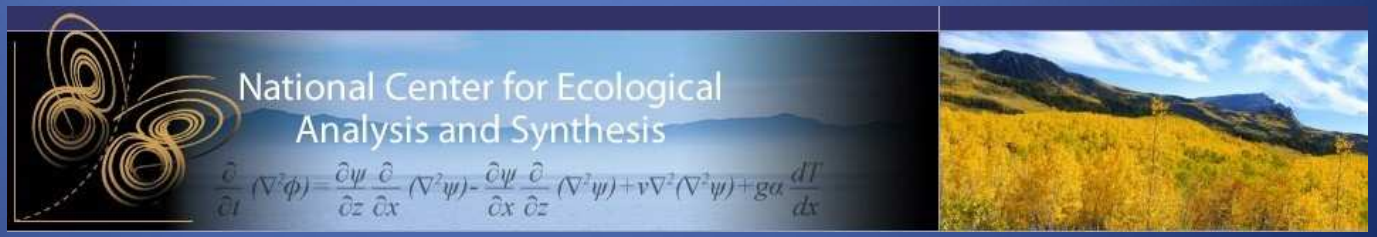
- Map social values (SolVES) and biophysically modeled ecosystem service (ARIES/others)
  - Identify “hotspots” and tradeoffs between ecosystem services & social values (Alessa et al. 2008, Bryan et al. 2011)
- Integrate into NF/NP planning & management (Cape Lookout NS, NC; Pike-San Isabel NF, CO; beyond)





Toward nationally applicable approaches: National Ecosystem Services Partnership

"Incorporating values and assessing social and environmental trade-offs in managing for ecosystem services"



"A standard assessment framework for ecosystem services"

Acknowledgements

- BLM-USGS Ecosystem Services Valuation Pilot colleagues, esp. Dave Goodrich, Malka Pattison, Mark Rekshynskyj
- ARIES project team, esp. Gary Johnson, Ferdinando Villa
- InVEST project team, esp. Chris Colvin, Driss Ennaanay, Heather Tallis, Stacie Wolny
- September 2010 San Pedro ecosystem services expert review panel

Publications

- Bagstad, K.J., D. Semmens, R. Winthrop, D. Jaworski, and J. Larson. 2012. Ecosystem services valuation to support decision making on public lands: A case study for the San Pedro River, Arizona. USGS Scientific Investigations Report 2012-5251.
- Bagstad, K.J., D. Semmens, and R. Winthrop. 2013a. Alternative approaches to spatially explicit ecosystem service modeling: A case study from the semiarid San Pedro River basin, Arizona. Ecosystem Services 5:40-50.
- Bagstad, K.J., D. Semmens, S. Waage, and R. Winthrop. 2013b. A comparative assessment of tools for ecosystem services quantification and valuation. Ecosystem Services 5:27-39.
- Bagstad, K.J., D. Semmens, F. Villa, and G.W. Johnson. In press. Quantifying and valuing ecosystem services: An application of ARIES to the San Pedro River basin, USA. Forthcoming in: Economics of Biodiversity and Ecosystem Services, Edward Elgar.


Thanks!
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