Evaluating Ecosystem Services with Remote Sensing

Amber McCullum, Juan L. Torres-Pérez, Guest Speakers Becky Chaplin-Kramer (Stanford) and Ken Bagstad (USGS)

Aug. 25, 2022

Course Structure and Materials

- Three, 1.5 -hour sessions on August 23, 25, & 30 at 11:00-12:30 EDT (UTC-4) (English)
- Webinar recordings, PowerPoint presentations, and the homework assignment can be found after each session at:
  - https://appliedsciences.nasa.gov/join-mission/training/english/arset-evaluating-ecosystem-services-remote-sensing
  - Q&A following each lecture and/or by email at:
    - amberjean.mccullum@nasa.gov or juan.l.torresperez@nasa.gov

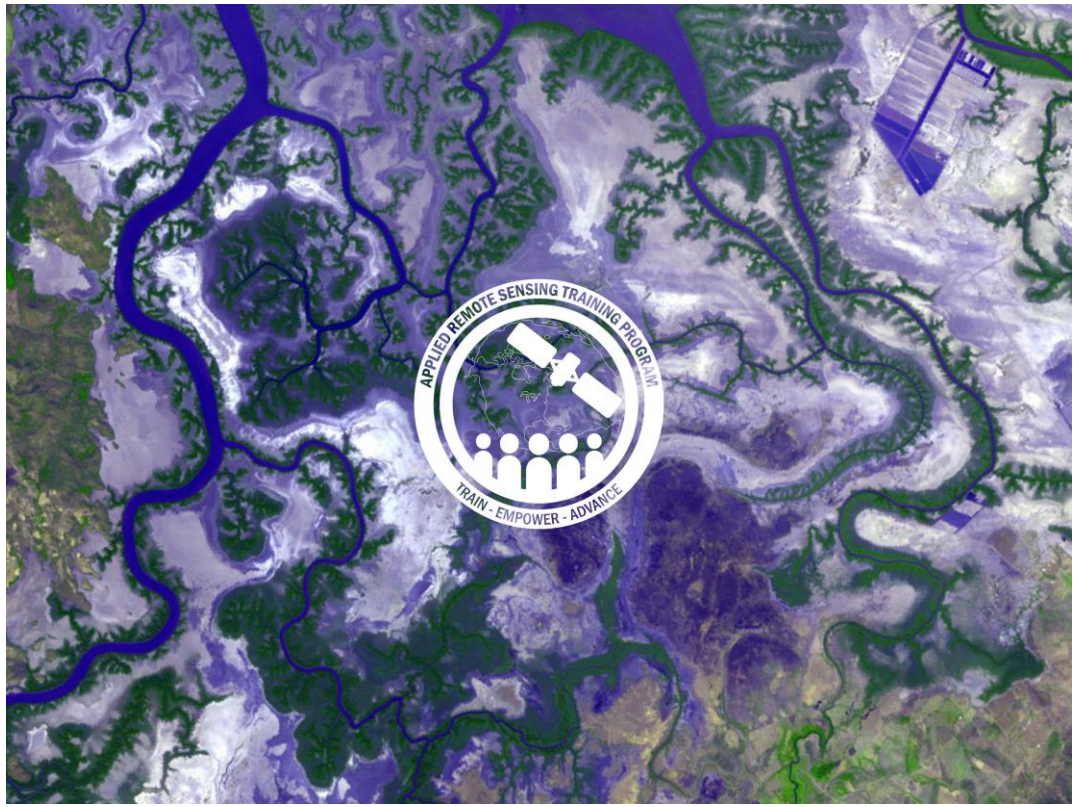
Homework and Certificates

- **Homework:**
  - One homework assignment
  - Answers must be submitted via Google Forms
  - **HW Deadline: Tuesday, September 13th**

- **Certificate of Completion:**
  - Attend all three live webinars
  - Complete the homework assignment by the deadline (access from ARSET website)
  - You will receive certificates approximately two months after the completion of the course from: marines.martins@ssaihq.com

Prerequisites

- Prerequisites:
  - Please complete Sessions 1 & 2A of Fundamentals of Remote Sensing or have equivalent experience.
- Course Materials:
  - https://appliedsciences.nasa.gov/join-mission/training/english/arset-evaluating-ecosystem-services-remote-sensing



Learning Objectives

By the end of this session, you will become familiarized with:

- How to link remote sensing to ecosystem assessments and accounting
- Multiple decision support tools for ecosystem assessments and accounting
- The Natural Capital Project and Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST)
- Artificial Intelligence for Environment and Sustainability (ARIES)

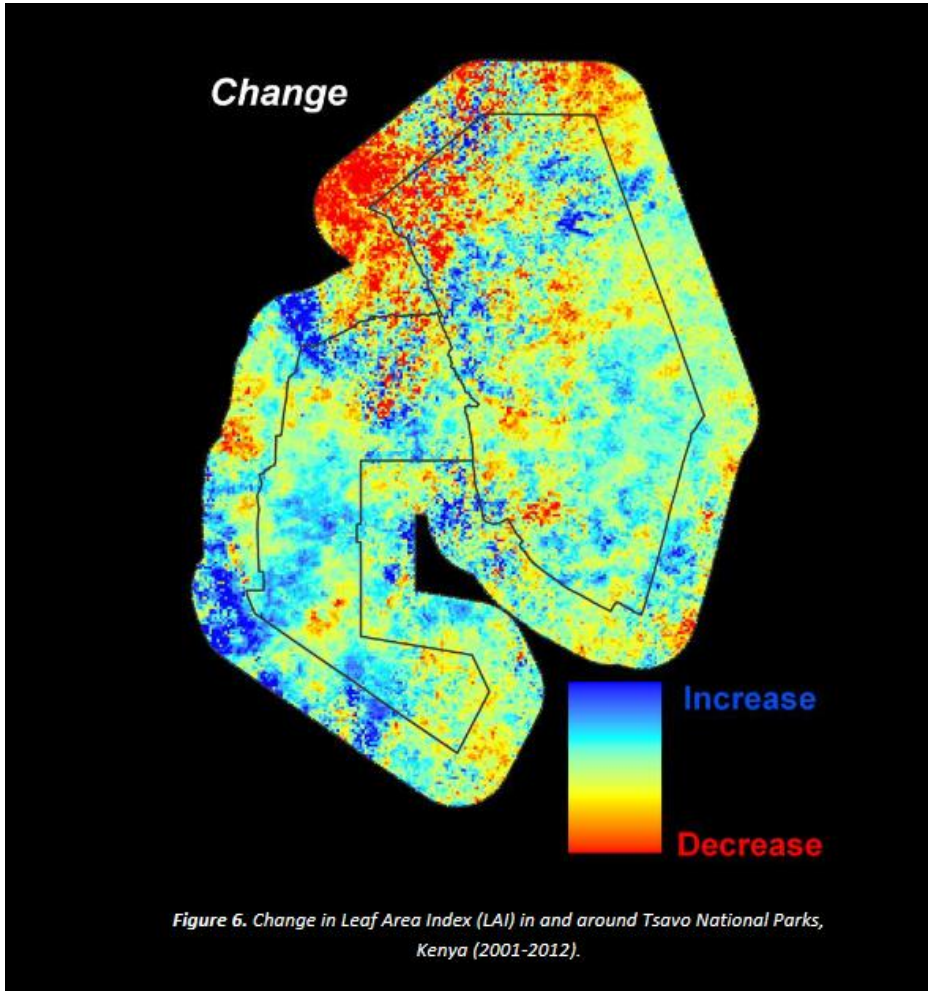


Figure 6. Change in Leaf Area Index (LAI) in and around Tsavo National Parks, Kenya (2001-2012).

Chauvenet, et. Al, 2015

Session 1 Review

- Ecosystem services are the benefits people obtain from ecosystems.
- Quantifying the value of the ecosystem service benefits is important.
- Many countries are using established frameworks for natural capital accounting.
  - UN System of Environmental-Economic Accounting (SEEA)
- Remote sensing can play a role in environmental economic accounting.
  - Land Cover Mapping
  - Additional Land Cover Metrics and Products

Linking Remote Sensing to Ecosystem Assessments and Accounting

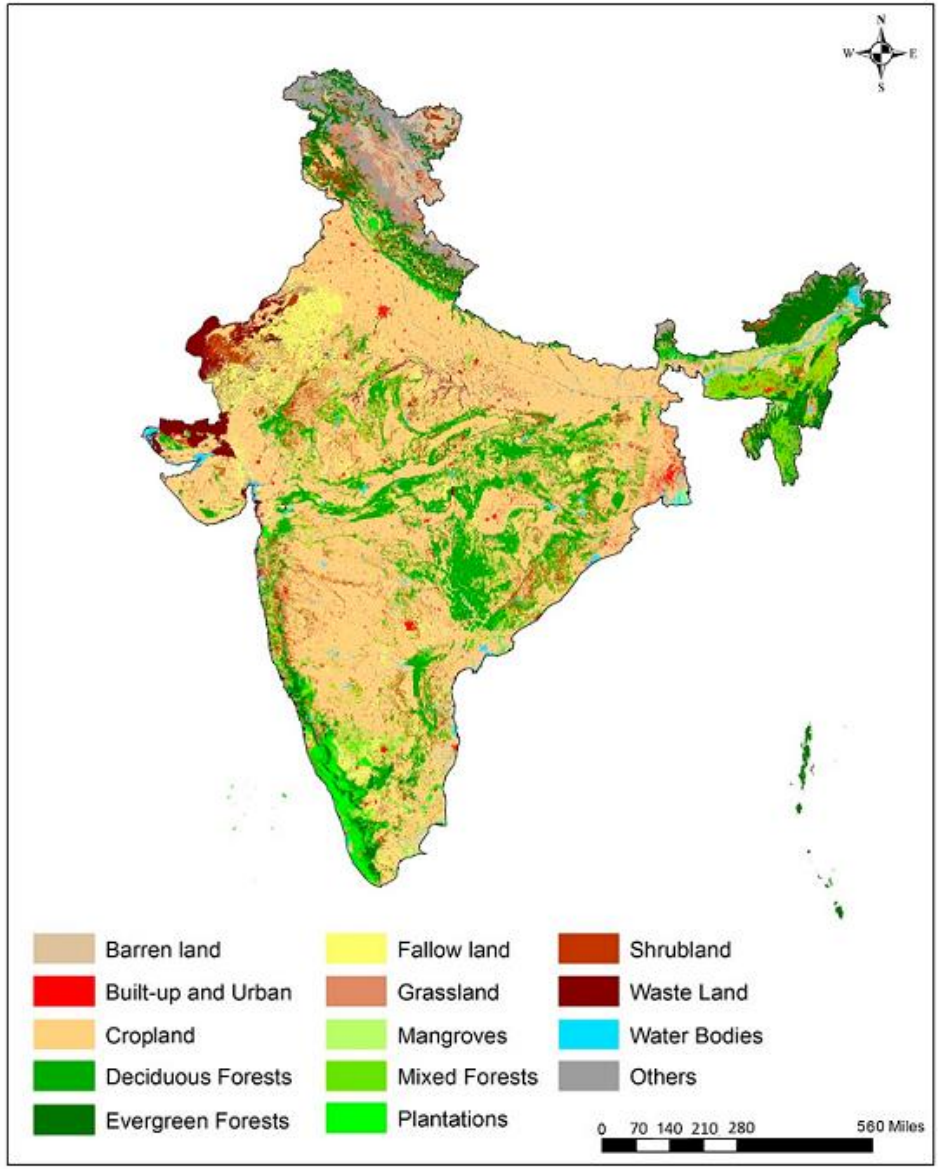
Ecosystem Assessments and Accounting Questions

- What habitat types, and how much of each, are present in the area of interest?
  - How have habitats changed over time?
- How much woody biomass is present in the area of interest?
- What is the canopy structure of the area of interest?
- What is the state of coastal wetlands and mangroves in the area of interest?
- What are the patterns in annual primary productivity in the area of interest?
- What is the amount of carbon stored and how is it changing in the area of interest?

Chauvenet, et. Al, 2015

Habitat Extent

- What habitat types, and how much of each, are present in the area of interest?
  - How have habitats changed over time?
- Land Cover Maps
  - Global Products via MODIS, VIIRS, SPOT, MERIS
  - Create your own via Landsat or Sentinel-2



Land use and land cover map of India for 2005. This map served as a reference for the 1995 and 1985 LULC maps (Roy et al., 2015).

Woody Biomass

- How much woody biomass is present in the area of interest?
  - Woody biomass is expressed as the weight of dry matter (e.g., wood, twigs) per unit area.
- Data: NDVI via MODIS, VIIRS, Landsat, Sentinel-2, etc.
  - Use a simple mathematical equation to transform NDVI into woody biomass.

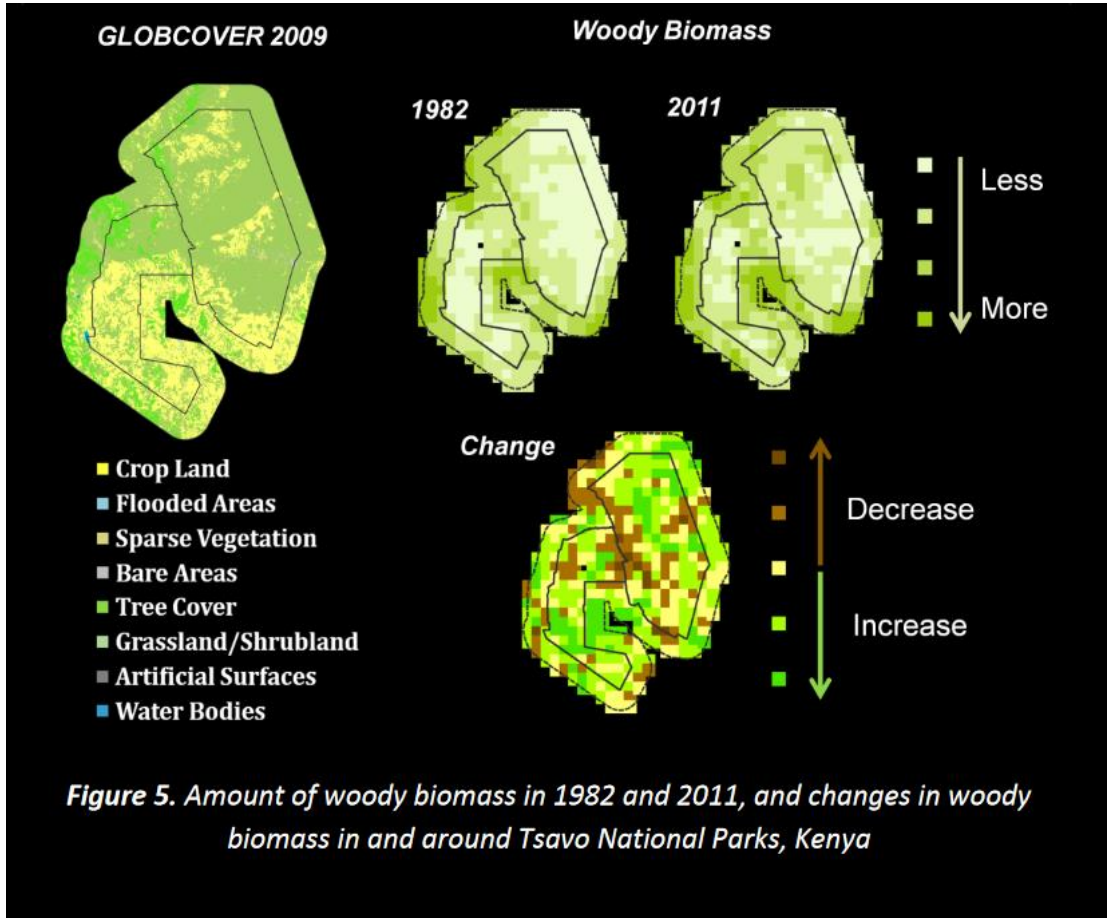


***Figure 5.** Amount of woody biomass in 1982 and 2011, and changes in woody biomass in and around Tsavo National Parks, Kenya*

Image Credit: Chauvenet, et. Al, 2015

Canopy Structure

- What is the canopy structure of the area of interest?
  - Leaf Area Index (LAI)
    - MODIS/VIIRS
  - Leaf Area Density (LAD)
    - Airborne LiDAR
  - Canopy Clumping
    - Airborne LiDAR

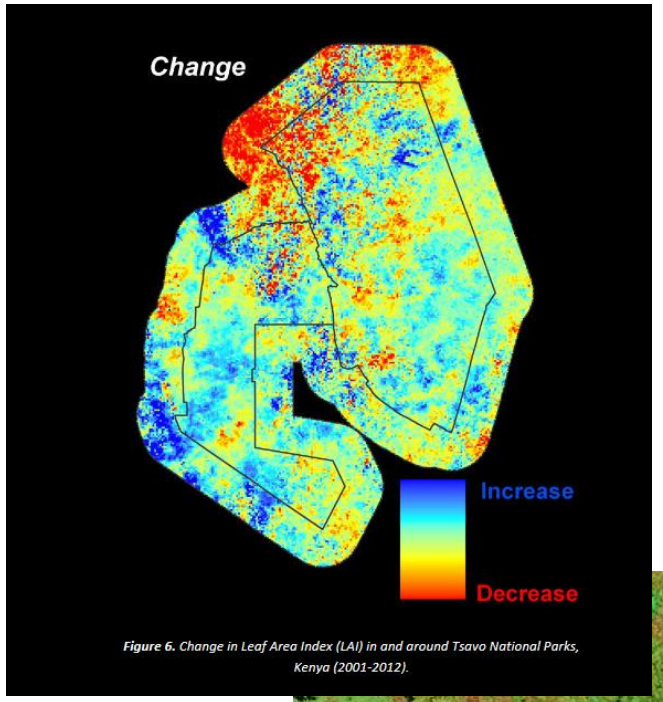
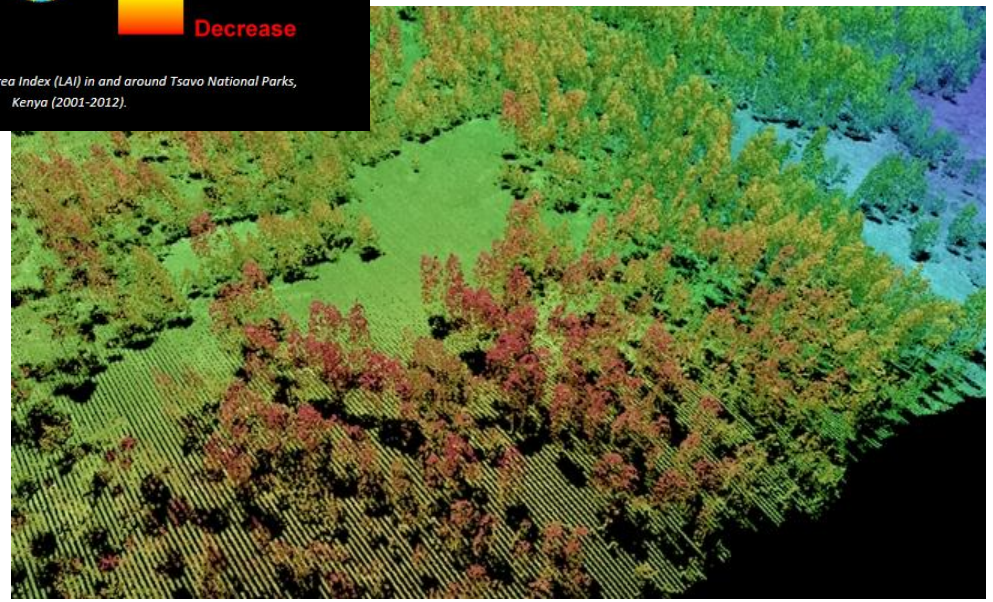


Figure 6. Change in Leaf Area Index (LAI) in and around Tsavo National Parks, Kenya (2001-2012).

Chauvenet, et. Al, 2015



Lidar point cloud forest stand: Image Credit: Marek Jakubowski

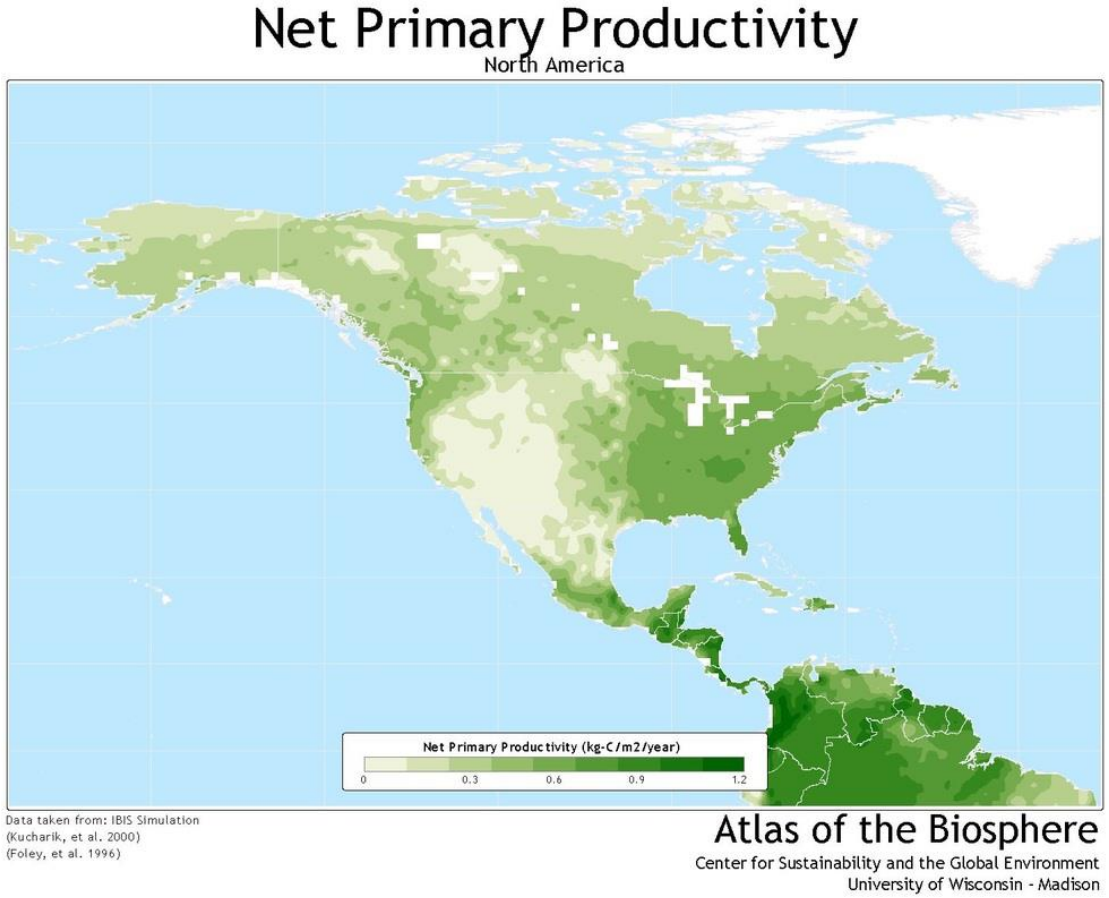
Mangrove Mapping

- What is the state of coastal wetlands and mangroves in the area of interest?
- Provide protection against floods, hurricanes, tsunamis
- Water quality
- Sink for nutrients and carbon
- We can measure extent, change height, biomass, and carbon stock using:
  - Passive Optical
  - Synthetic Aperture Radar
  - LiDAR
- Previous ARSET Training: Mangrove Mapping in support of UN SDGs: https://appliedsciences.nasa.gov/join-mission/training/english/arset-remote-sensing-mangroves-support-un-sustainable-development

Imagery of the Sundarbans, Image Credit: Jesse Allen with the Earth Observatory

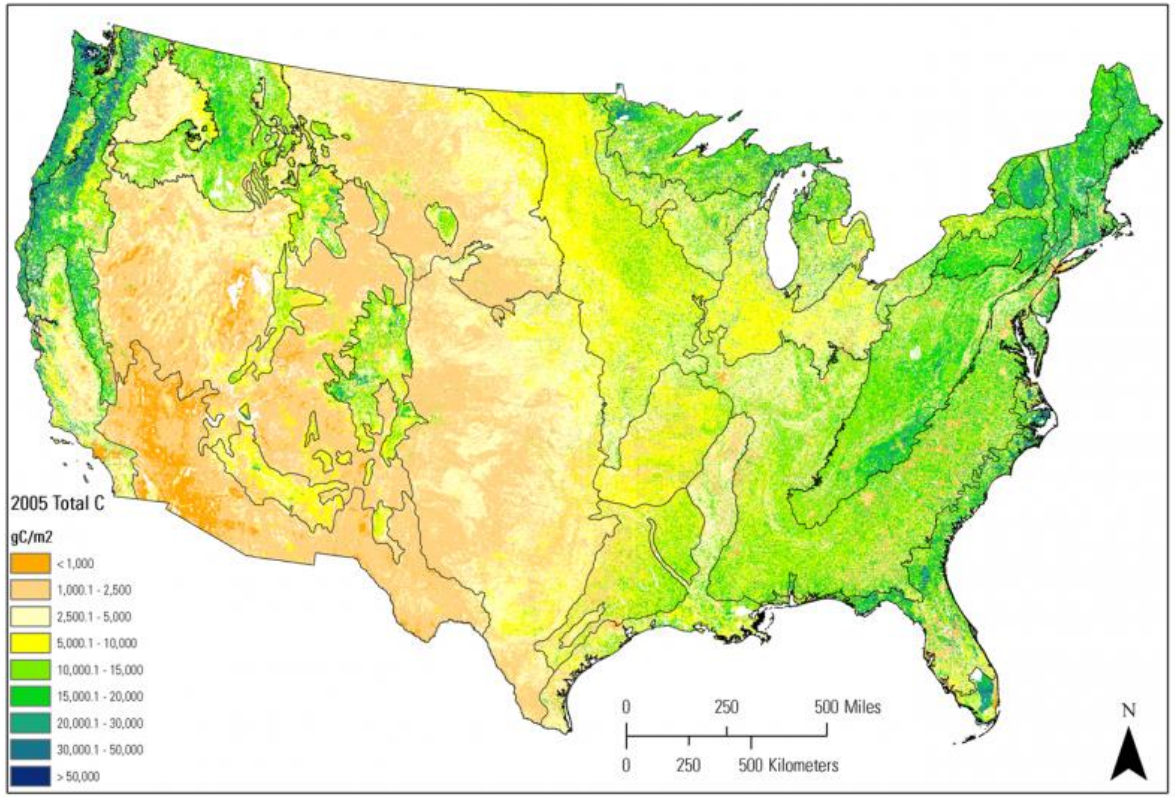
Primary Productivity

- What are the patterns in annual primary productivity in the area of interest?
- Primary productivity is an important component of the global carbon budget and is used as an indicator of ecosystem function.
- NDVI as one indicator (MODIS, VIIRS, Landsat, Sentinel-2, etc.)
- Net Primary Productivity (NPP) Products: MODIS Global Average NPP



Carbon Storage

- What is the amount of carbon stored and how is it changing in the area of interest?
- Carbon sinks are critical for a system's ability to mitigate for climate change.
- Linked to above-ground biomass
- REDD+ country accounting
- In-situ measurements and remotely-sensed vegetation indices: NDVI, EVI
- Previous ARSET Training: Forest Cover and Change Assessment for Carbon Monitoring



Average amount of carbon stored in all terrestrial ecosystems in the conterminous United States in 2005 as estimated by a national assessment of carbon stocks and sequestration capacity performed by the U.S. Geological Survey.

Decision Support Tools for to Ecosystem Assessments and Accounting

Decision Support Tools for Ecosystems Services

- Tools must provide the ability for assessments to be quantifiable, replicable, credible, flexible, and affordable (Bagstad, et al., 2013).

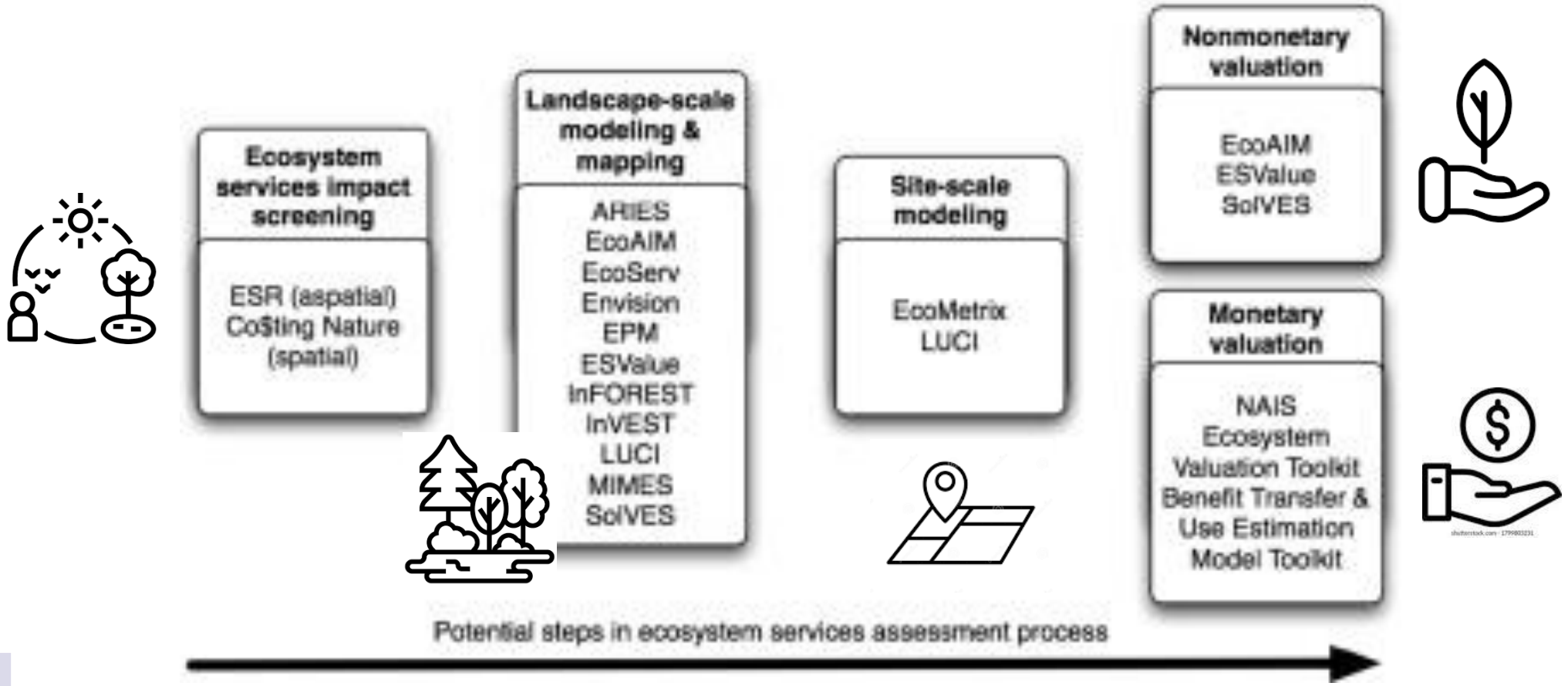
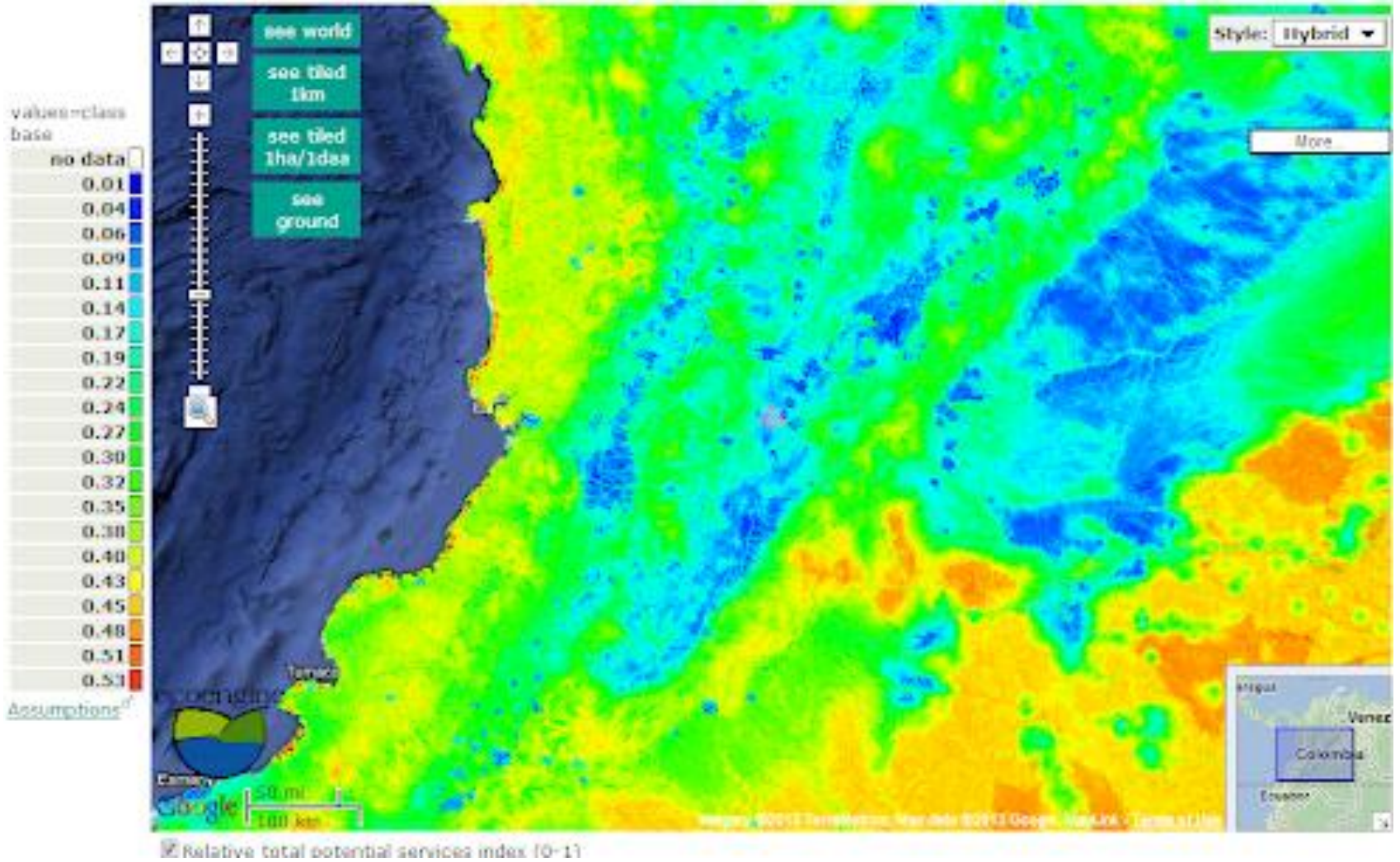


Image Credit: Modified from Bagstad, et al., 2013

Co$ting Nature

http://www.policysupport.org/costingnature

- Web-based spatial policy support system for natural capital accounting and analyzing the ecosystem services provided by natural environments, identifying the beneficiaries of these services, and assessing the impacts of human interventions.
- Global coverage
- 1 km spatial resolution for countries and major basins

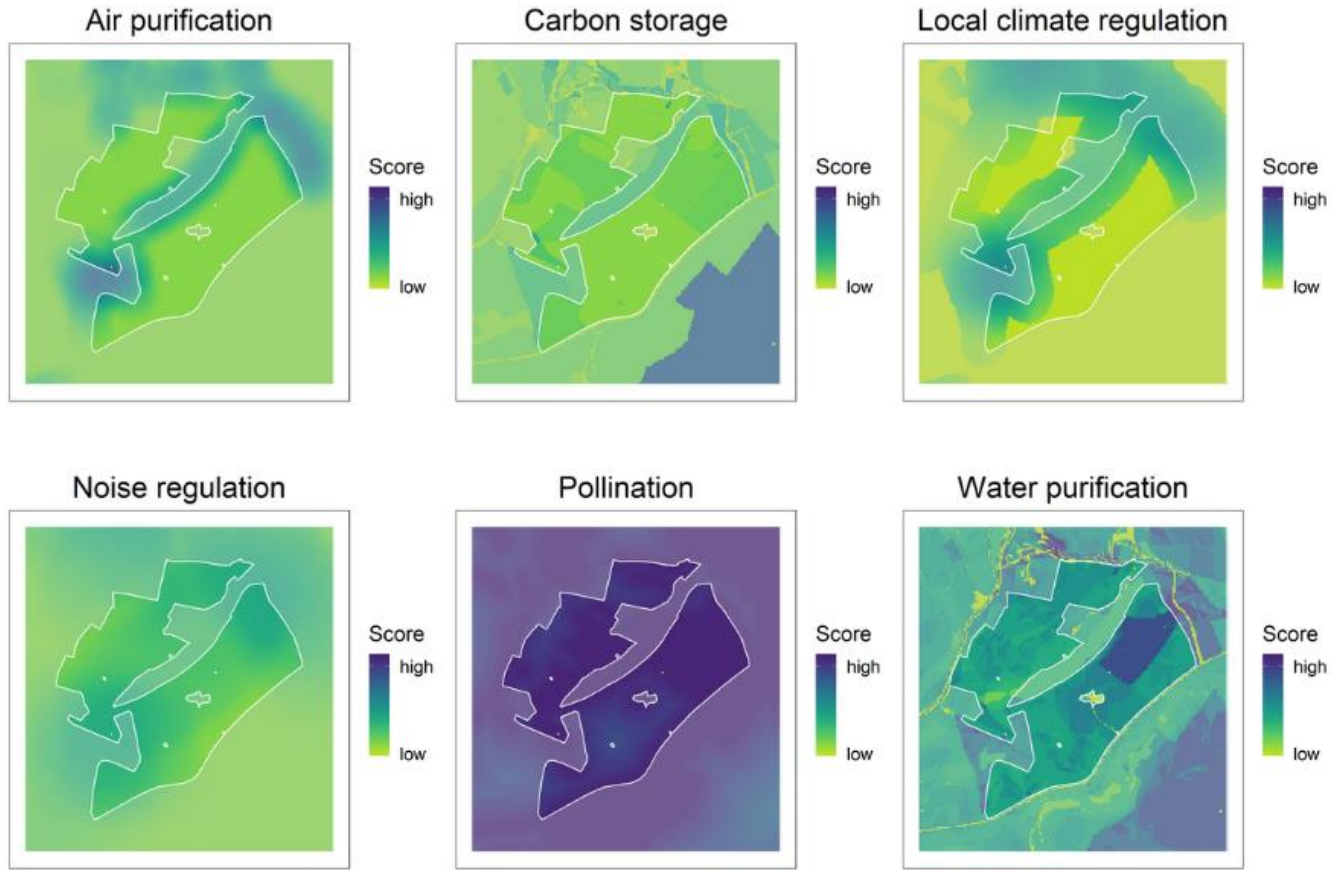


Example of Relative Total Potential Services Index from Colombia.
Image Credit: CPWF Compandes

EcoServ-GIS and EcoServR

https://ecoservr.github.io/EcoservR/

- United Kingdom focus
- EcoServ-GIS: Standardized methods and maps that can be freely shared
  - Ecosystem service capacity
  - Service demand areas
  - Service benefiting areas
- EcoServR: Rewrite of EcoServ-GIS
- EcoservR measures and maps a range of ecosystem services. The current toolkit includes:
  - Carbon storage
  - Air purification
  - Water purification
  - Pollination
  - Local climate regulation
  - Noise regulation
  - Accessible nature



Example of capacity score maps for a farm holding in Cheshire

Image Credit: EcoServR

Envision

http://envision.bee.oregonstate.edu/

- A GIS-based tool for scenario-based community and regional integrated planning and environmental assessments, developed at Oregon State
- Open-source and freely available
- Multiagent Modeling Subsystem: Human decision-makers and landscape simulations

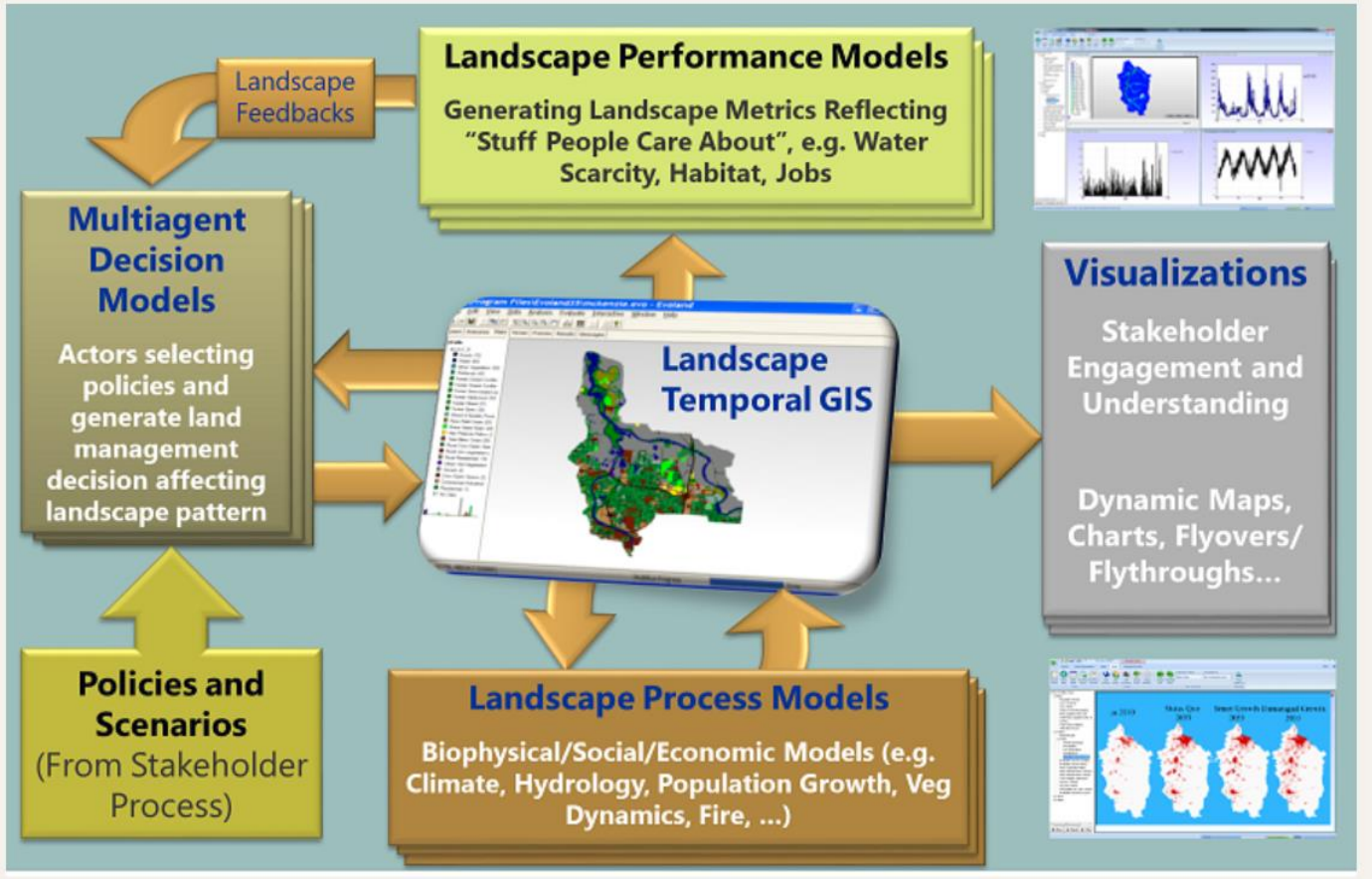
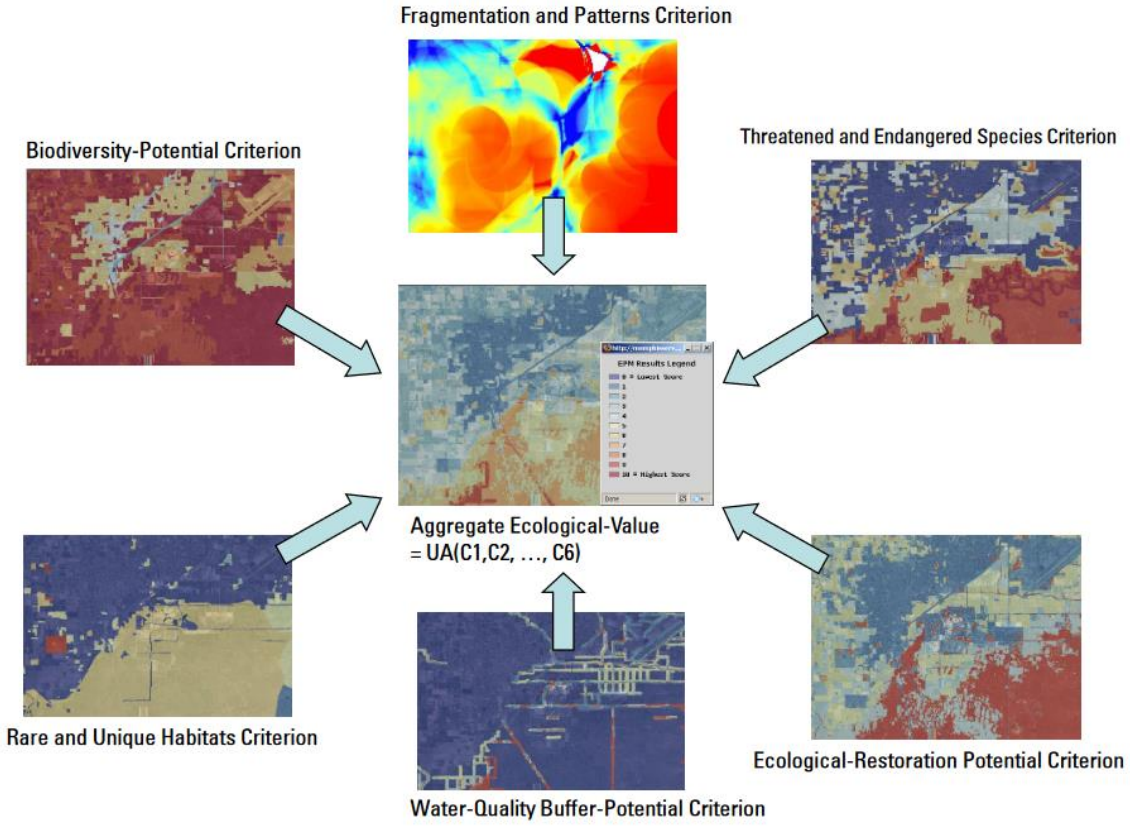


Image Credit: Envision

Ecosystem Portfolio Model (EPM)

- Prototype that integrates ecological, socio-economic information and associated values of relevance to decision-makers and stakeholders
- Multi-criteria scenario evaluation framework in a GIS
  - Land use/land cover change models
  - Land cover-related ecosystem values
  - Land parcel prices
  - Community quality of life
- South Florida EPM Example:
  - Biodiversity potential
  - Threatened and endangered species
  - Rare and unique habitats
  - Water quality buffer potential
  - Landscape patterns and fragmentation
  - Ecological restoration potential

https://pubs.usgs.gov/sir/2009/5181/



Cell-by-cell aggregation of individual ecological-criteria utility (value) maps into ecological-value maps using a multi-attribute utility function. Image Credit: Labiosa, et al. 2009

InFOREST

http://inforest.frec.vt.edu/

- Developed by the State of Virginia - Only Available Here
- Use map to identify area of interest and calculate ecosystem services on:
  - Air quality
  - Carbon sequestration
  - Nutrient and sediment runoff
  - Open lands

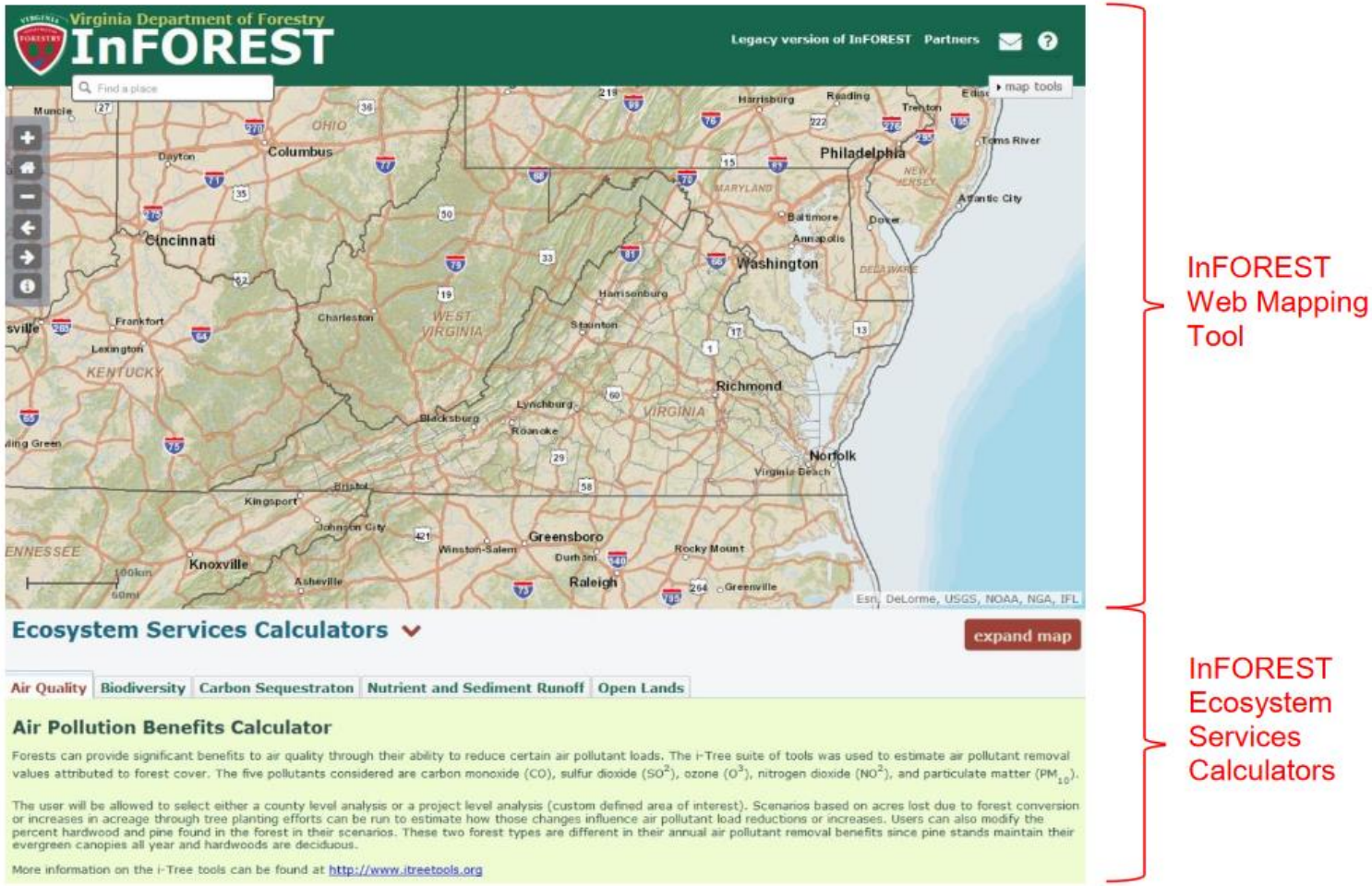
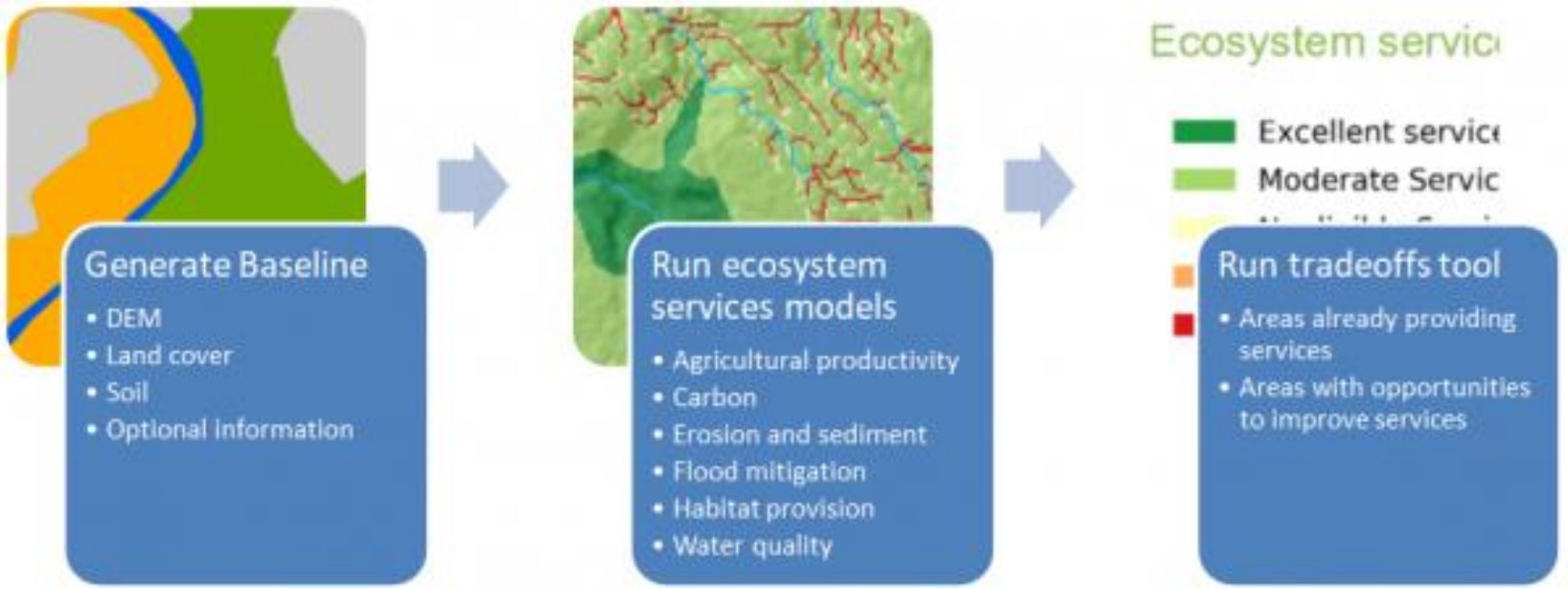


Image Credit: InFOREST

Land Utilization Capability Indicator (LUCI)

https://www.lucitools.org/using-luci/

- An ecosystem services modeling tool which illustrates the impacts of land use on various ecosystem services
- Used most extensively in the United Kingdom and New Zealand
- Requires three datasets to run:
  - Digital Elevation Model (DEM)
  - Land Cover Map
  - Soil Types



General flowchart for running LUCI. Image Credit: LUCI

ESValues

https://www.esvalues.org/

- A collaborative platform that collects economic data from ecosystem services studies to produce value estimates by benefit transfer

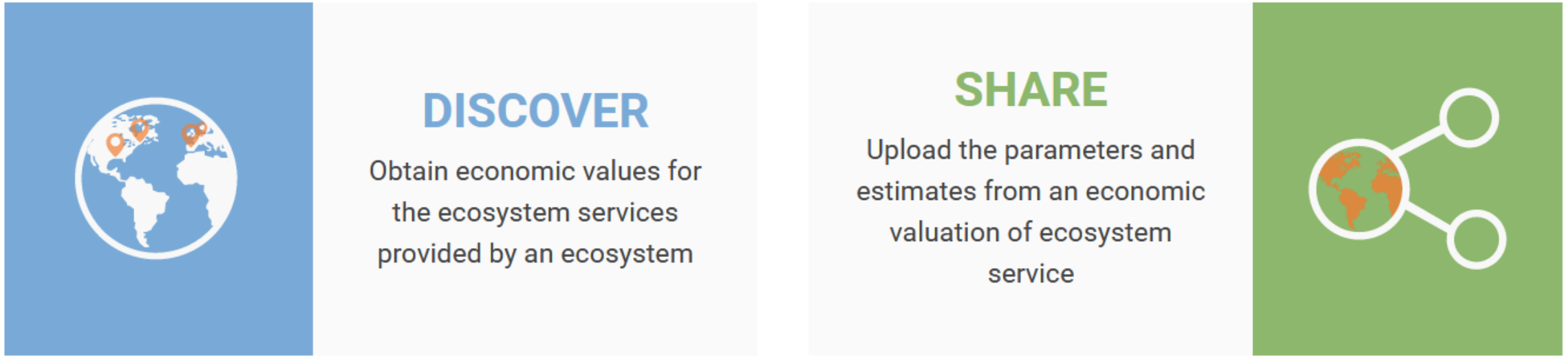


Image Credit: ESValues

- Search by valuation content, ecosystem services, and additional filters (e.g., regions/country/year) and get results from past work

Benefit Transfer Toolkit

https://sciencebase.usgs.gov/benefit-transfer/

- This toolkit compiles economic values estimates and other information on resources not priced in conventional markets.
- Benefit Transfer Approach: Transfers available information from original studies to estimate nonmarket economic values
  - Value Transfer
  - Function Transfer

Nonmarket Valuation Databases

Statistical Forecasting Models

Recreation Activities Map

Image Credit: USGS

Guest Speaker: Becky Chaplin-Kramer (Stanford)

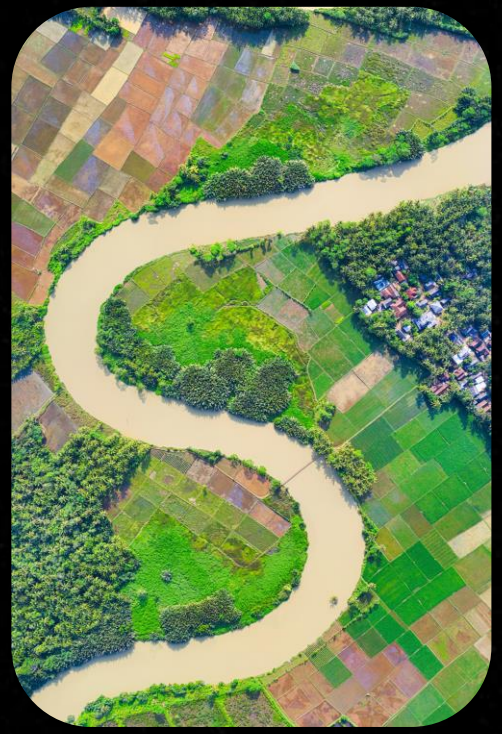
Mapping and Modeling Natural Capital

Introduction to InVEST

Becky Chaplin-Kramer

natural capital PROJECT

Stanford University



Science **Technology** **Partnerships** **IMPACT**

https://naturalcapitalproject.stanford.edu


natural capital PROJECT
Stanford University
Pioneering science, technology, and partnerships that enable people and nature to thrive.
Stockholm Resilience Centre
Sustainability Science for Biosphere Stewardship
Stockholm University
INSTITUTE ON THE ENVIRONMENT
UNIVERSITY OF MINNESOTA
Driven to Discover℠
CHINESE ACADEMY OF SCIENCES
The Nature Conservancy
WWF

SPRING

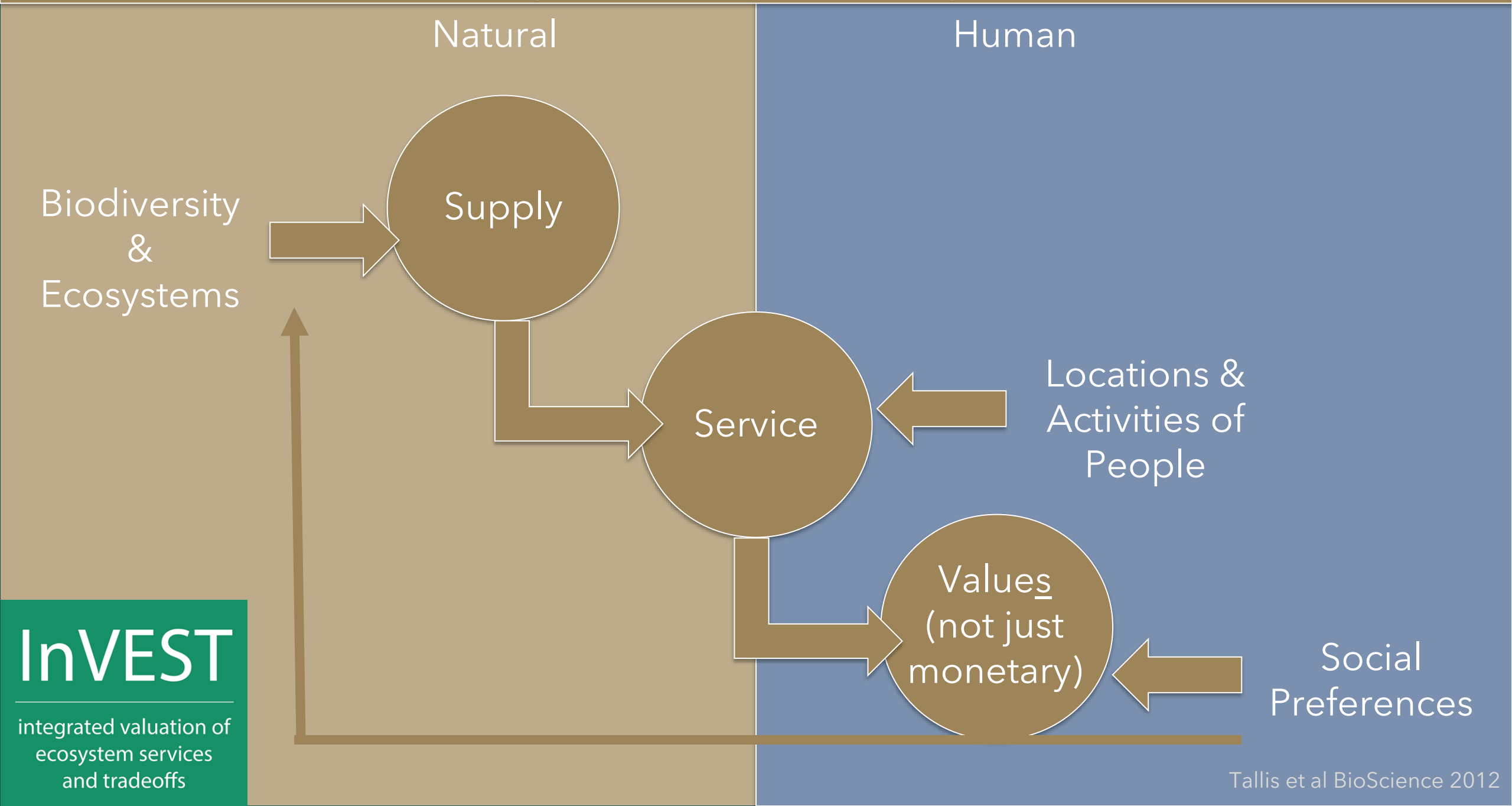
springinnovate.org

Innovation for nature.

Unleashing the power of science and software for planetary health and prosperity.

"You can only manage what you can measure."

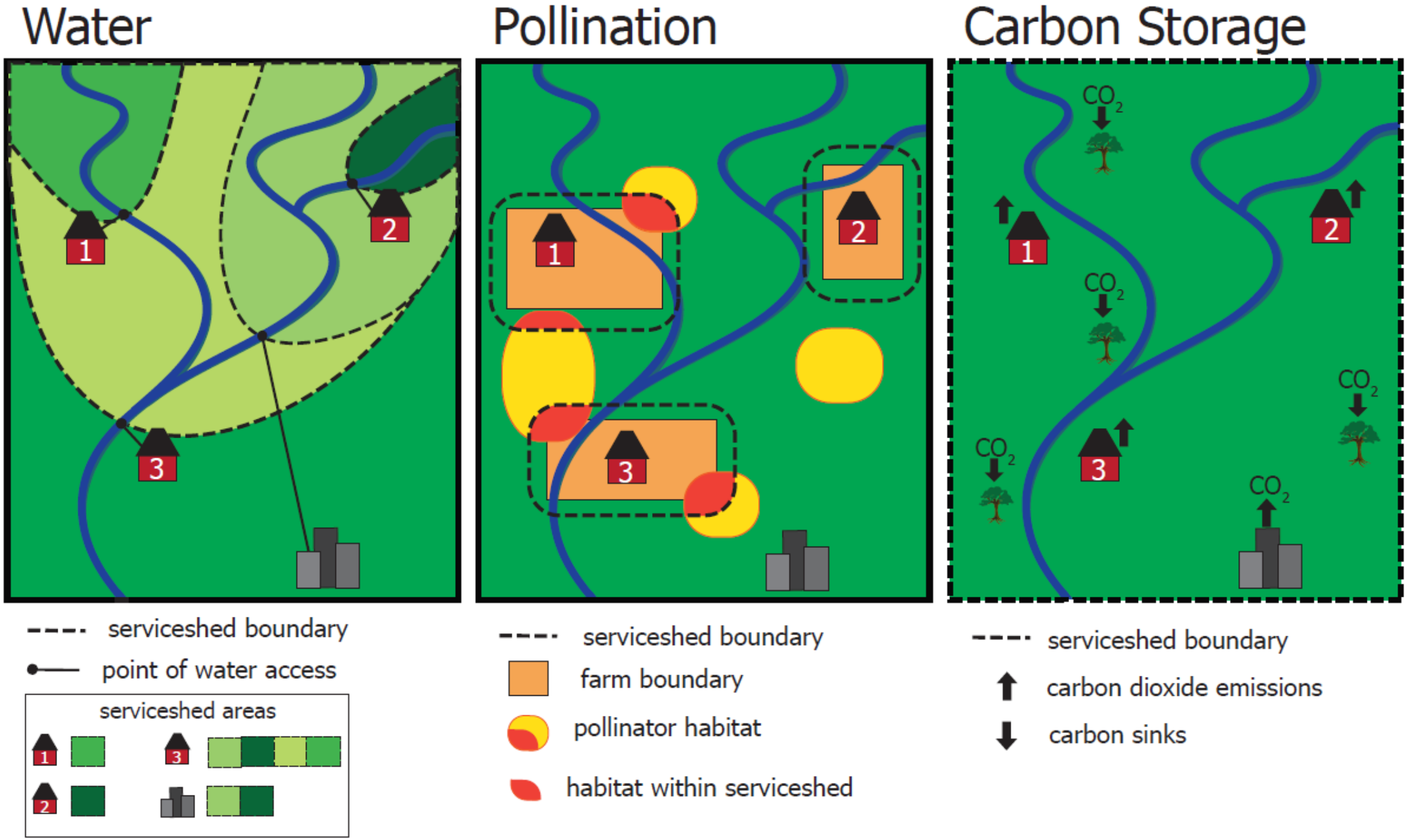
Coupled Natural & Human System



InVEST

integrated valuation of ecosystem services and tradeoffs

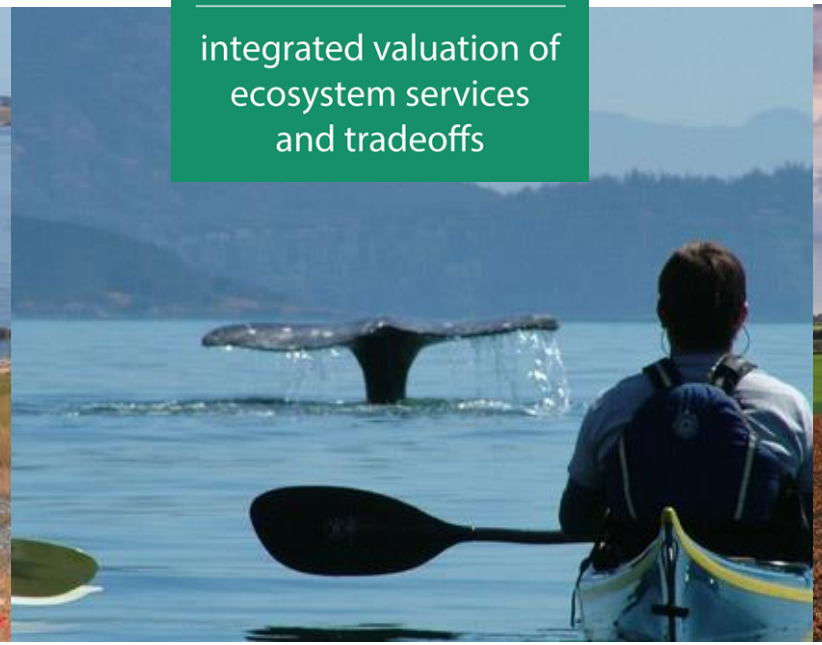
Tallis et al BioScience 2012


Water
Pollination
Carbon Storage
1
2
3
CO2
serviceshed boundary
point of water access
serviceshed areas
serviceshed boundary
farm boundary
pollinator habitat
habitat within serviceshed
serviceshed boundary
carbon dioxide emissions
carbon sinks

Changes in Ecosystems ➡
Changes in Ecosystem Services

InVEST

integrated valuation of ecosystem services and tradeoffs



Alternative Management, Policy → Δ Ecosystem Structure → Δ Ecosystem Service SUPPLY → Δ Ecosystem SERVICE → Δ Ecosystem Service VALUE

Habitat Restoration Decision

Streamside Habitat Area

Water Filtration & Retention

Sediment Load in Stream

Agricultural Yield

Avoided Treatment Cost

People Affected

Our Tools

InVEST
integrated valuation of ecosystem services and tradeoffs

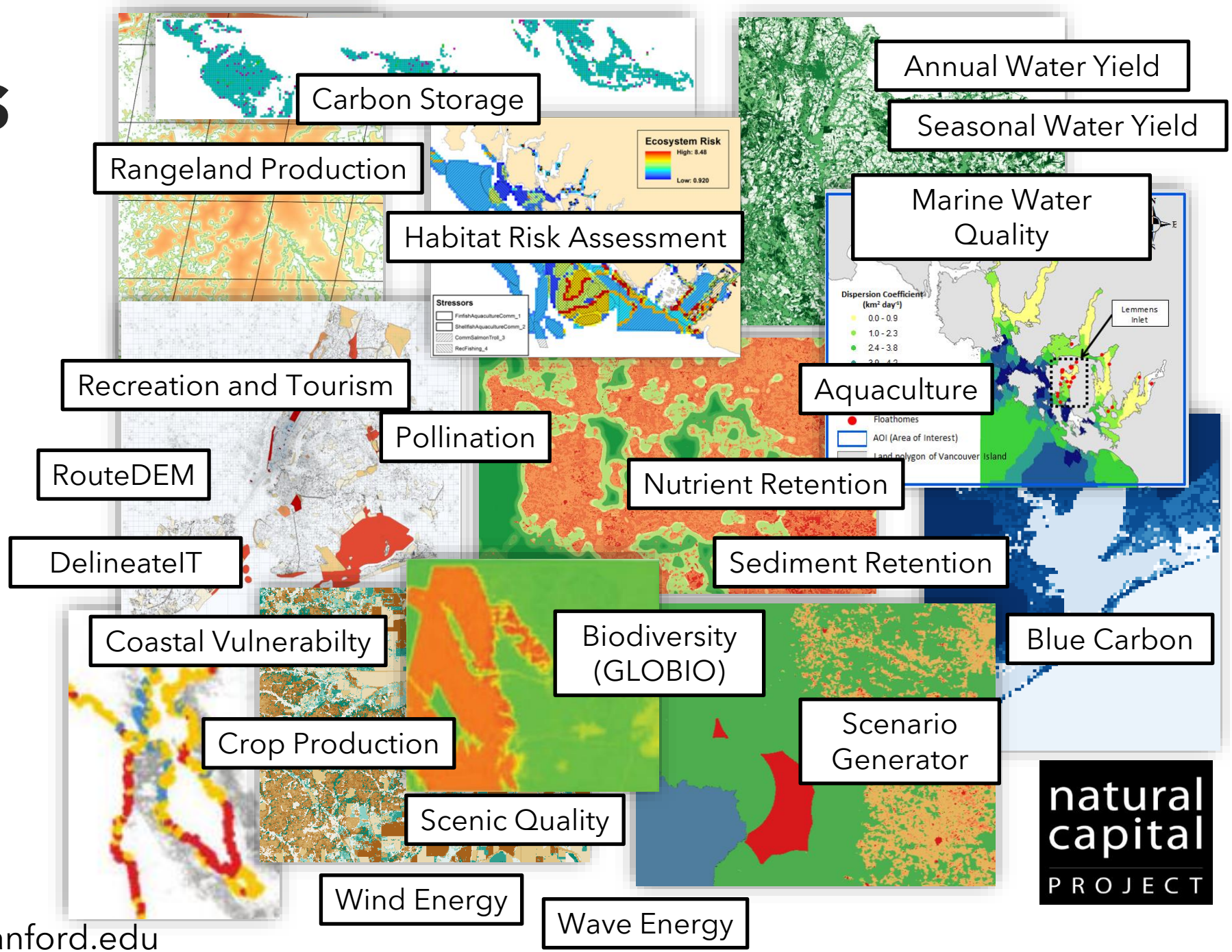
MESH

RIOS

PyGeoProcessing

OPAL

MARINE PLANNING CONCIERGE



natural capital PROJECT

naturalcapitalproject.stanford.edu

- Simple models
- Relatively simple data requirements
- Applicable across the globe
- Flexible scale
- Biophysical and economic outputs
- Allows multi-service assessment
- Free and open-source

InVEST

integrated valuation of ecosystem services and tradeoffs

From Scenarios to Services

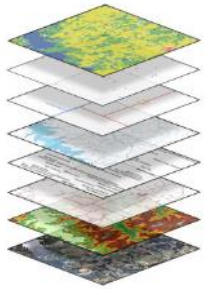
InVEST

integrated valuation of ecosystem services and tradeoffs

Input Data (Scenarios)	InVEST Models (Supply of ES)	Output Data from the Models

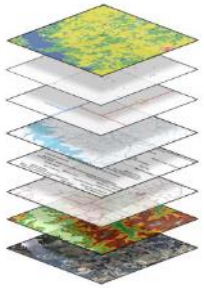
Land-Use

Biophysical-Climate



- Digital Elevation Model
- Precipitation
- Evapotranspiration
- Climate Zones
- Soil Type

Socio-Economic



- Population Density
- Demography
- Property Value

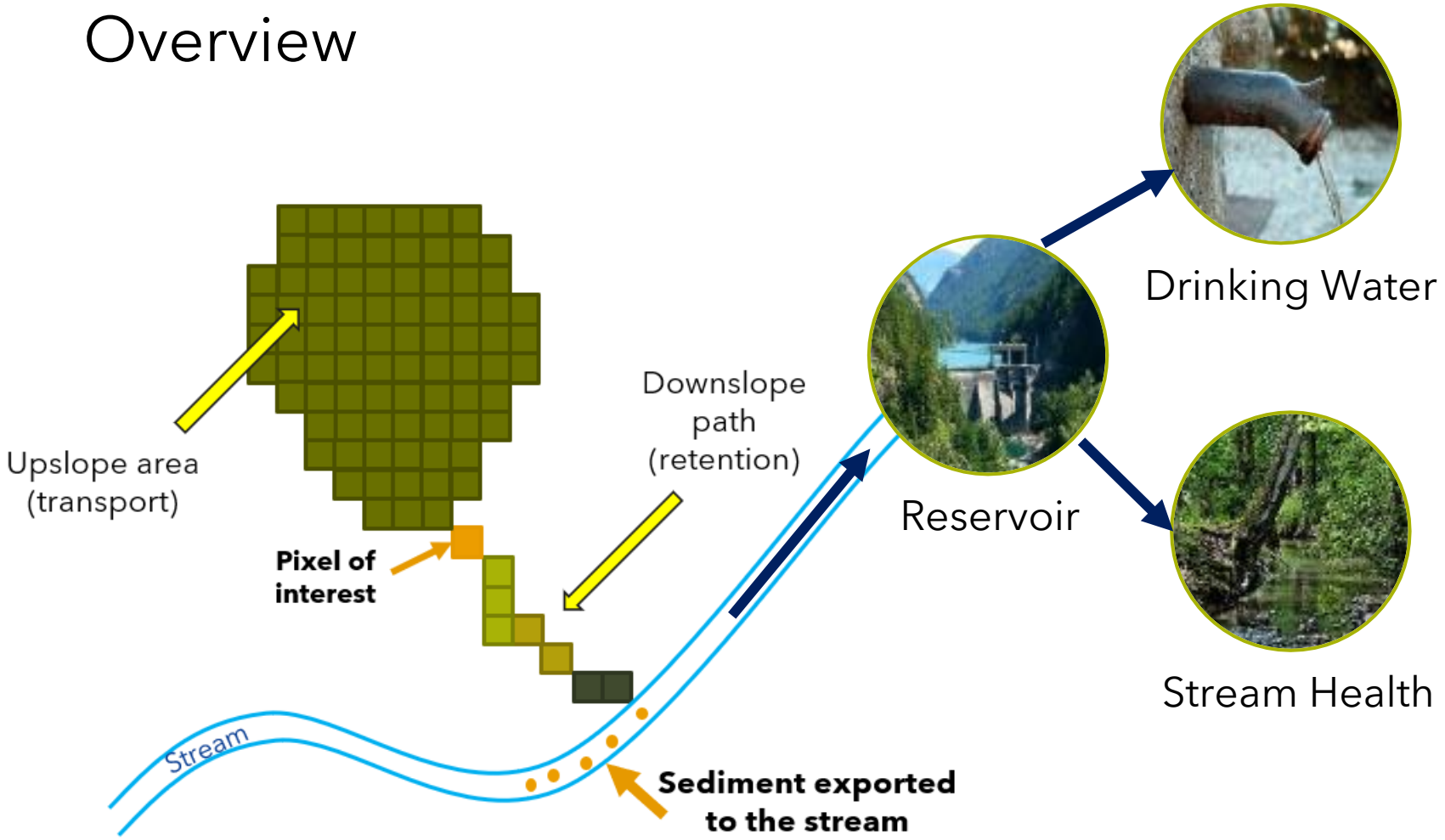
e.g.,

- Seasonal Water Yield (SWY)
- Sediment Retention (SDR)

Ecosystem Services	Valuation
Surface Runoff, Local Recharge, Baseflow	Value of the reduction of landslide risks, groundwater for consumption, water for agriculture
Sediment Export, Drinking Water Quality	Water treatment cost, health-related water quality impacts

Sediment Retention Model

Overview



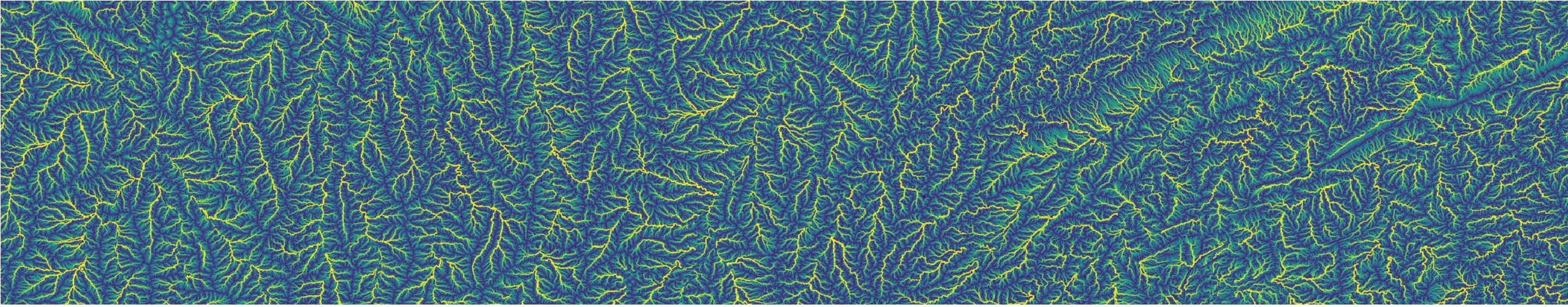
Supply: Sediment Retention

Service: Water Purification

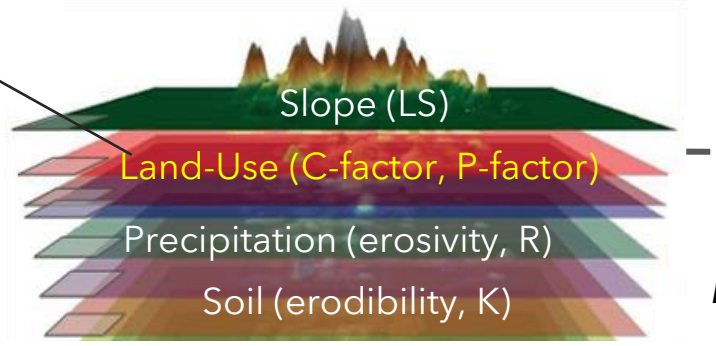
Value: Avoided Treatment/ Dredging

AIM

Understand the spatial patterns of sediment sources and transport to assess the value of natural landscapes

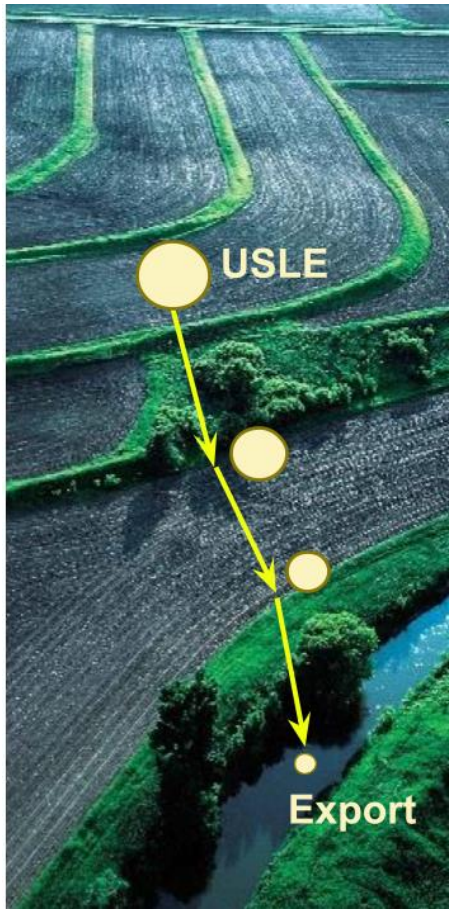


LULC	usle_c
Croplands	0.3651
Forest	0.0030
Grasslands	0.0792
Sparsely Vegetated	0.4140
Permanent Wetlands	0.0010
Urban and Built-Up	0.2739
Barren	0.9084
Water Bodies	0.0300



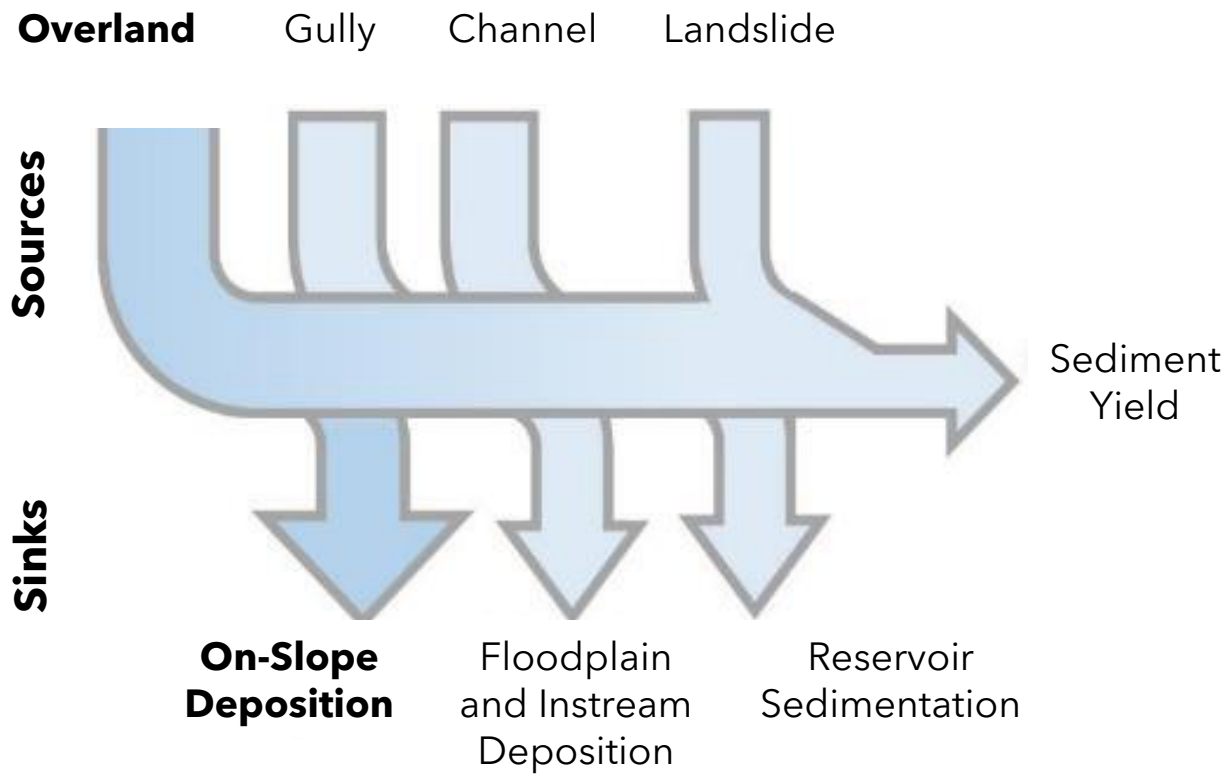
Universal Soil Loss Equation (USLE)

Soil Loss (ton/yr)= R x K x LS x C x P



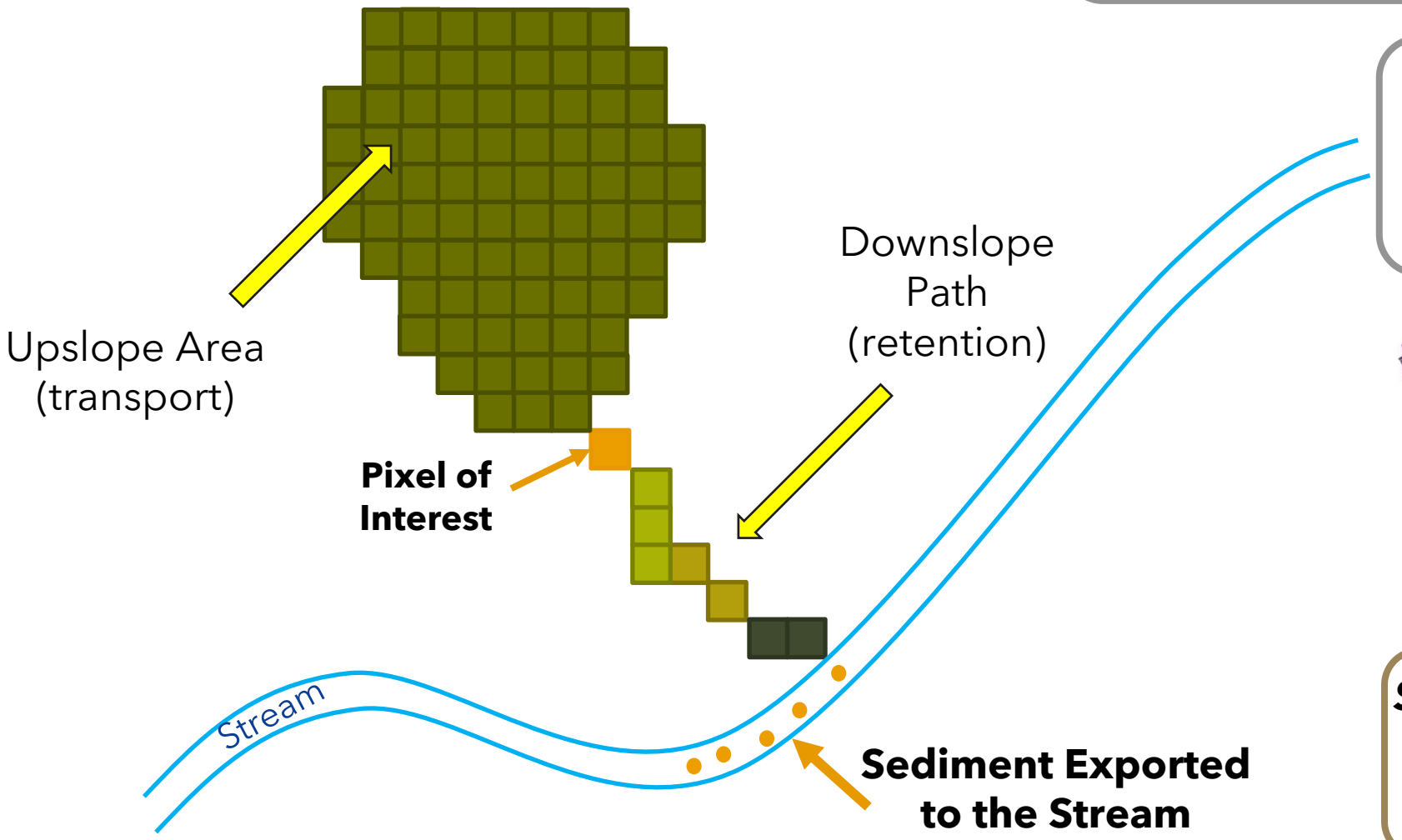
Universal Soil Loss Equation (USLE)

- Very popular method
- A LOT of literature
- BUT:
  - Only for **overland erosion**
  - Uncertainty in parameters:
    - **LS factor** for high slopes
    - **C-**, **P-factors**, etc.



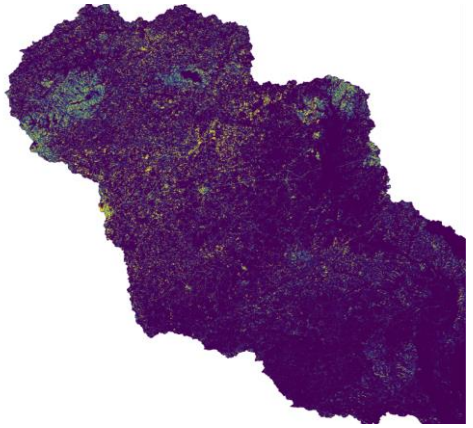
Sediment Delivery Ratio (SDR)

SDR is a function of **upslope transport** and **downslope retention**.



Per Pixel:

$$SedimentExport = USLE \times SDR$$



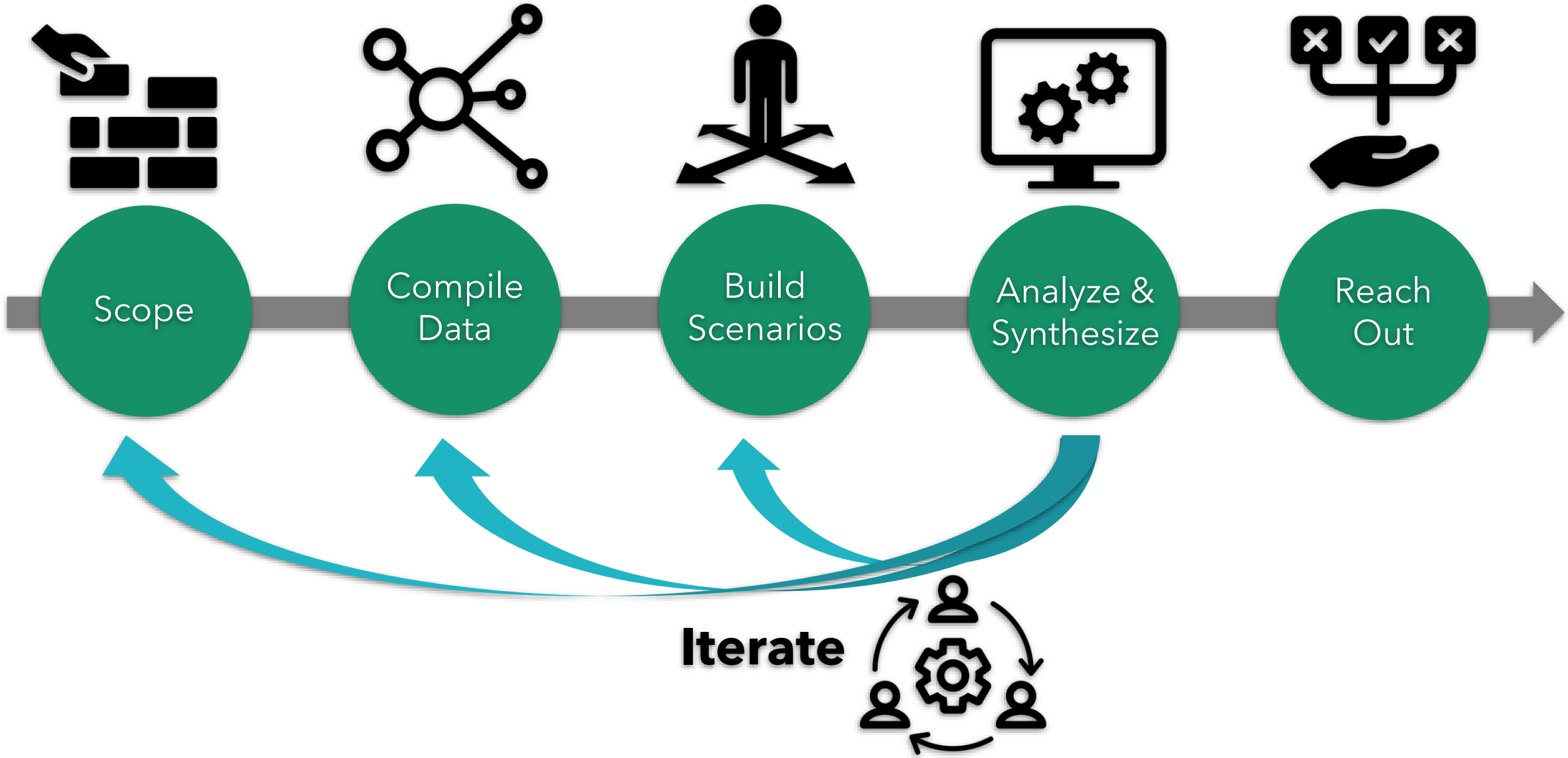
Sediment Retention =

$$\frac{(RKLS - USLE) \cdot SDR}{SDR_{max}}$$

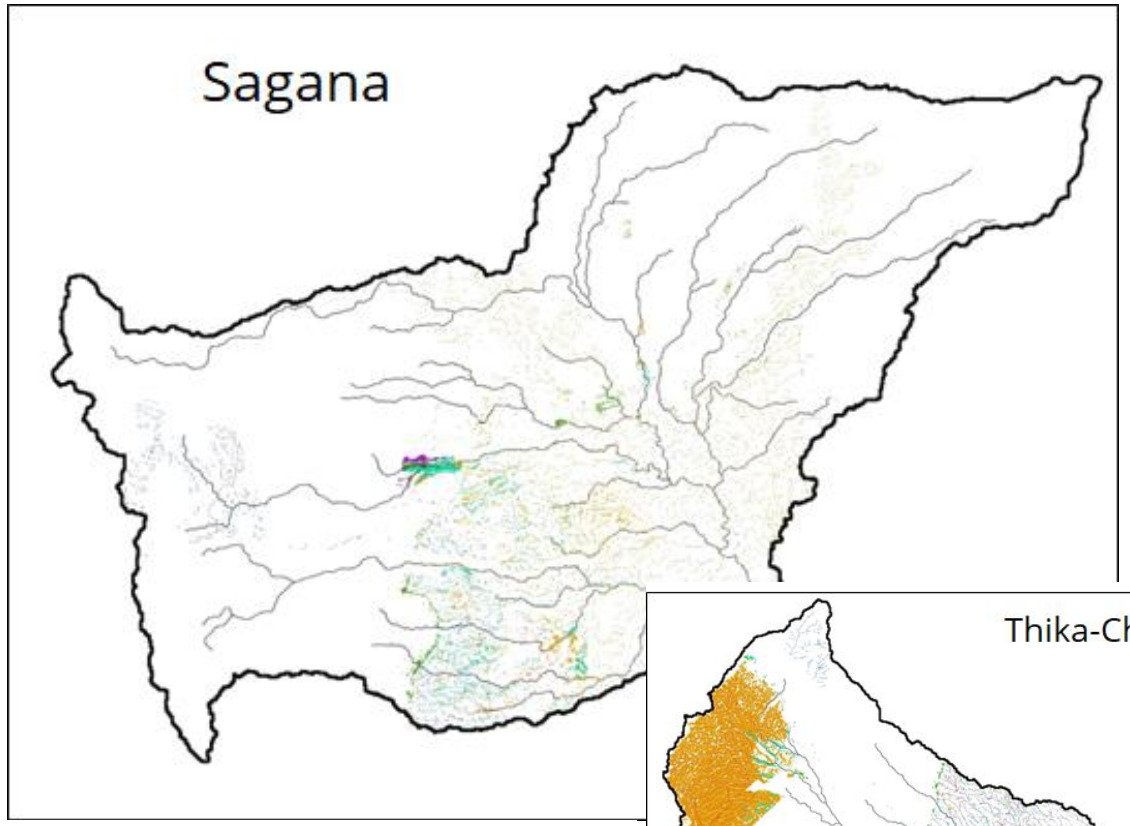
Valuation

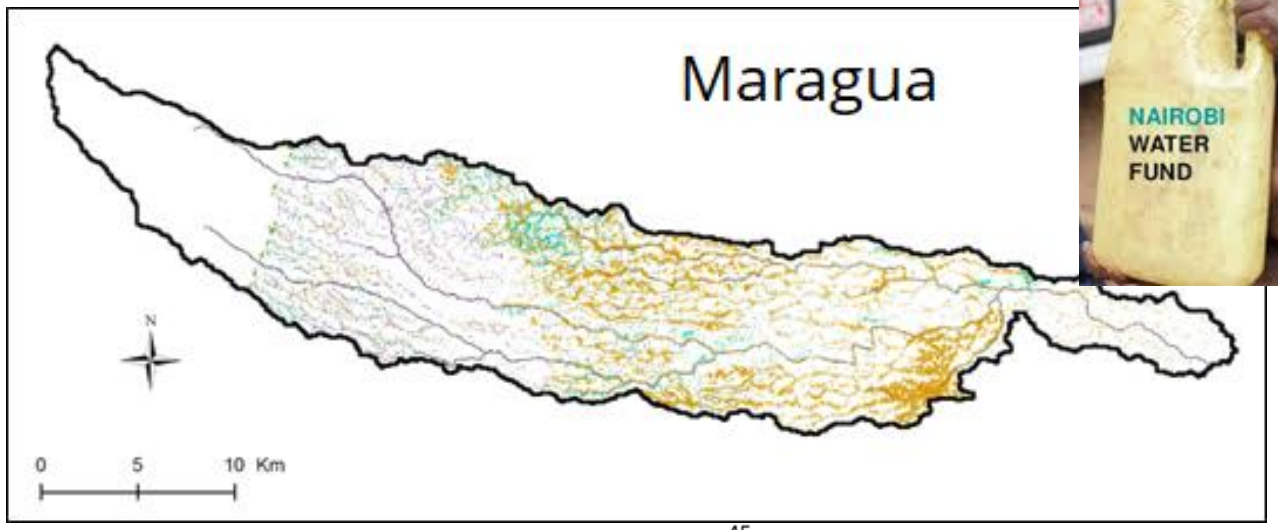
- Very context-specific!
- Example: Replacement and avoided cost approach

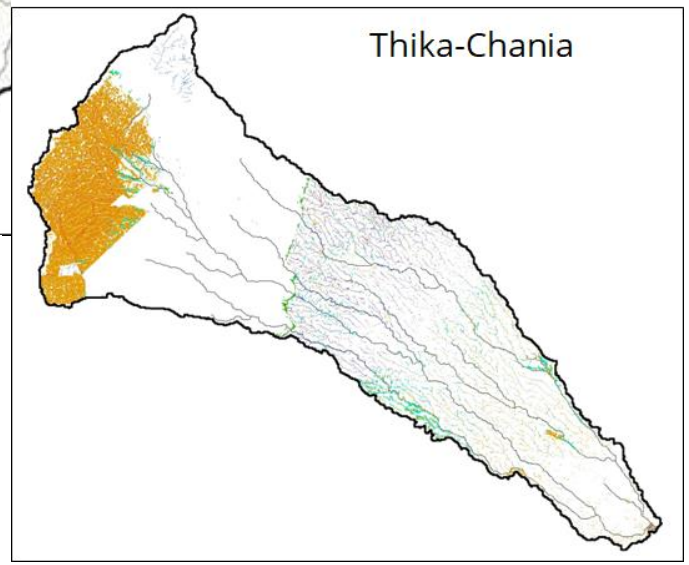
Assessment Process



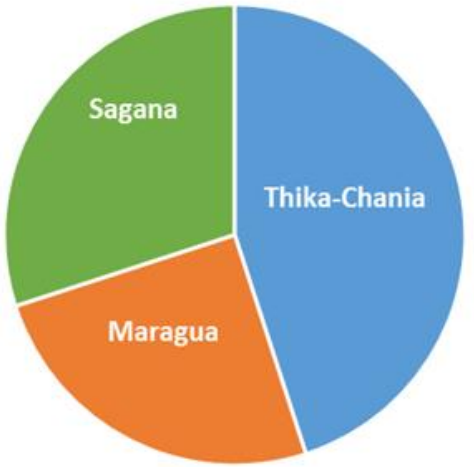
Ecosystem Service Prioritization in Watershed Planning

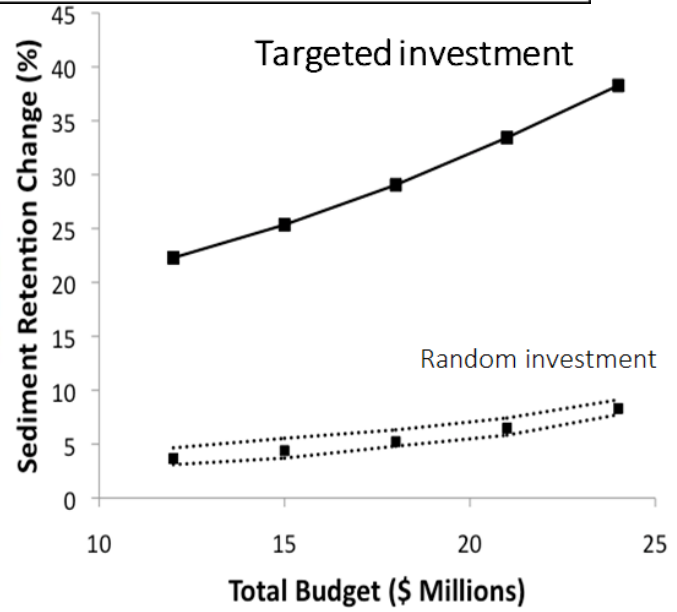




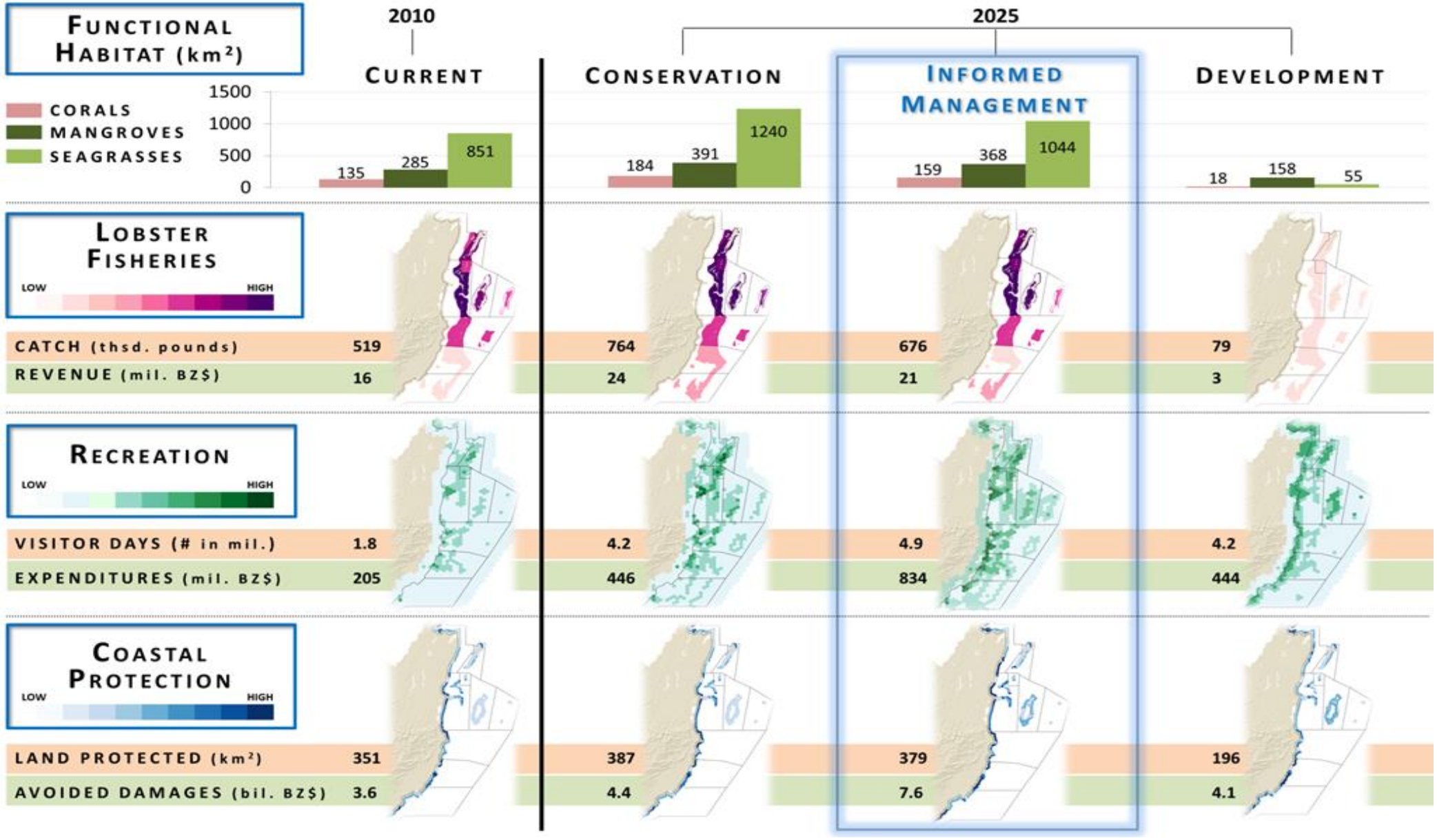


Agroforestry
Grass strips
Reforestation
Riparian management
Road mitigation
Terracing
Streams



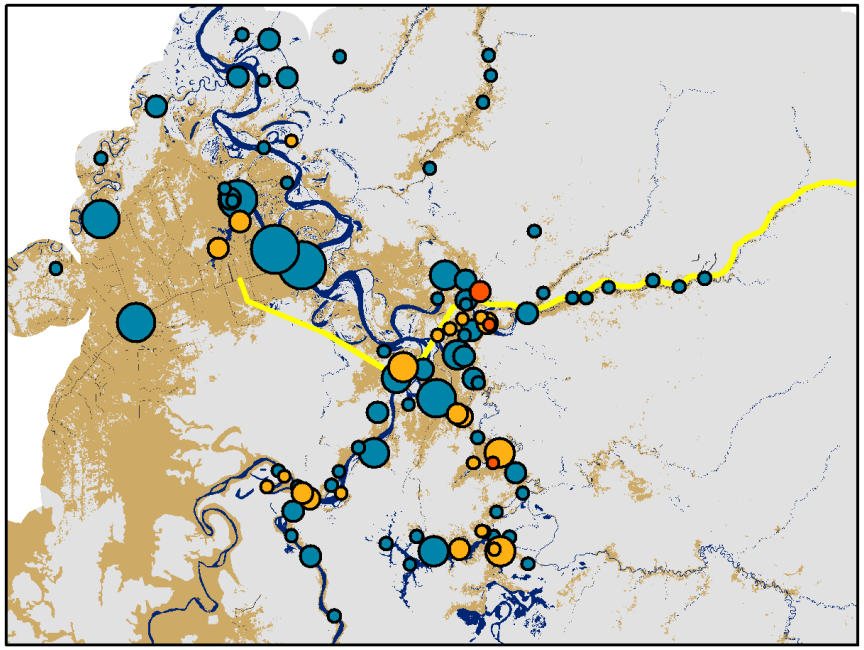


Spatial Planning via Scenario Assessment



Impacts and Mitigation of Development

Remaining impacts after mitigation:

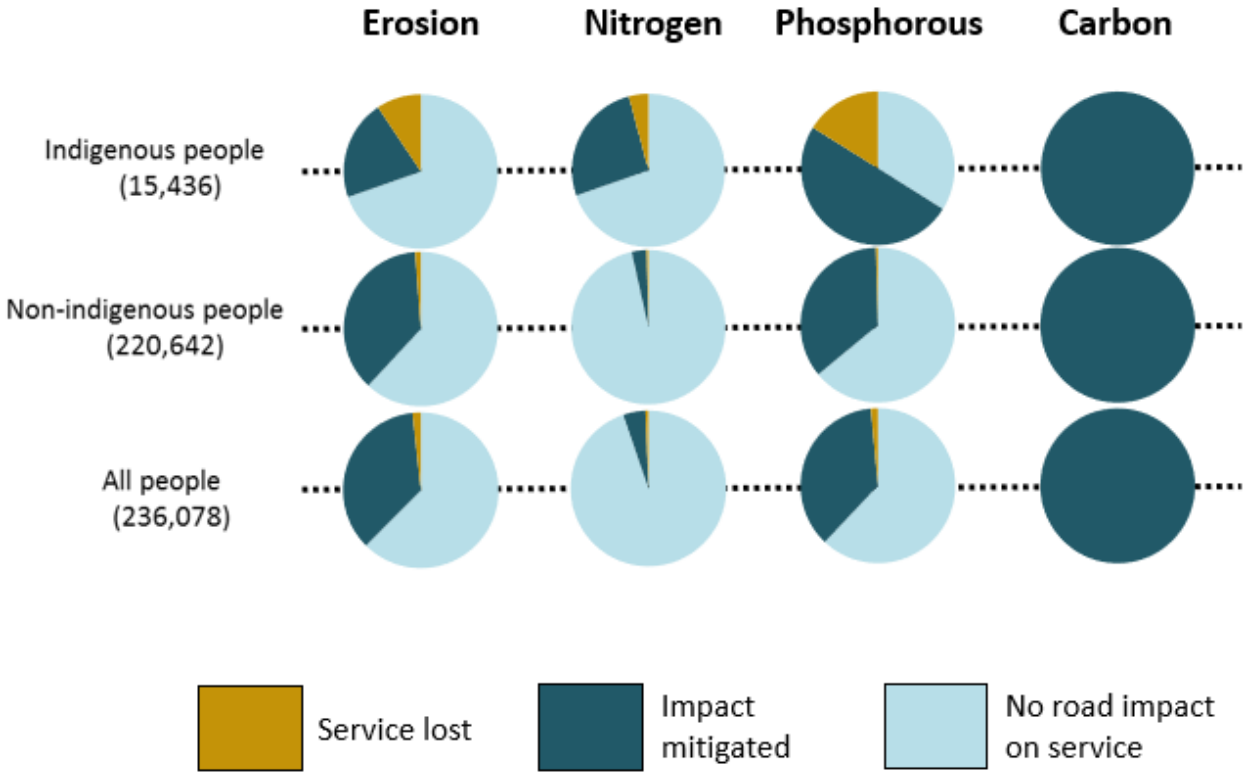


Population size

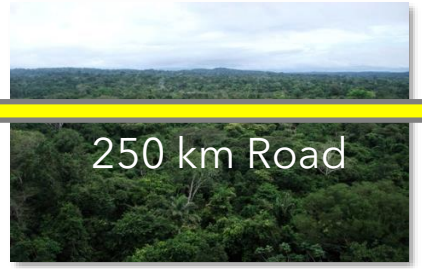
- < 250
- 250 - 500
- 500 - 1,000
- 1,000 - 5,000
- 5,000 - 130,000

Loss of services

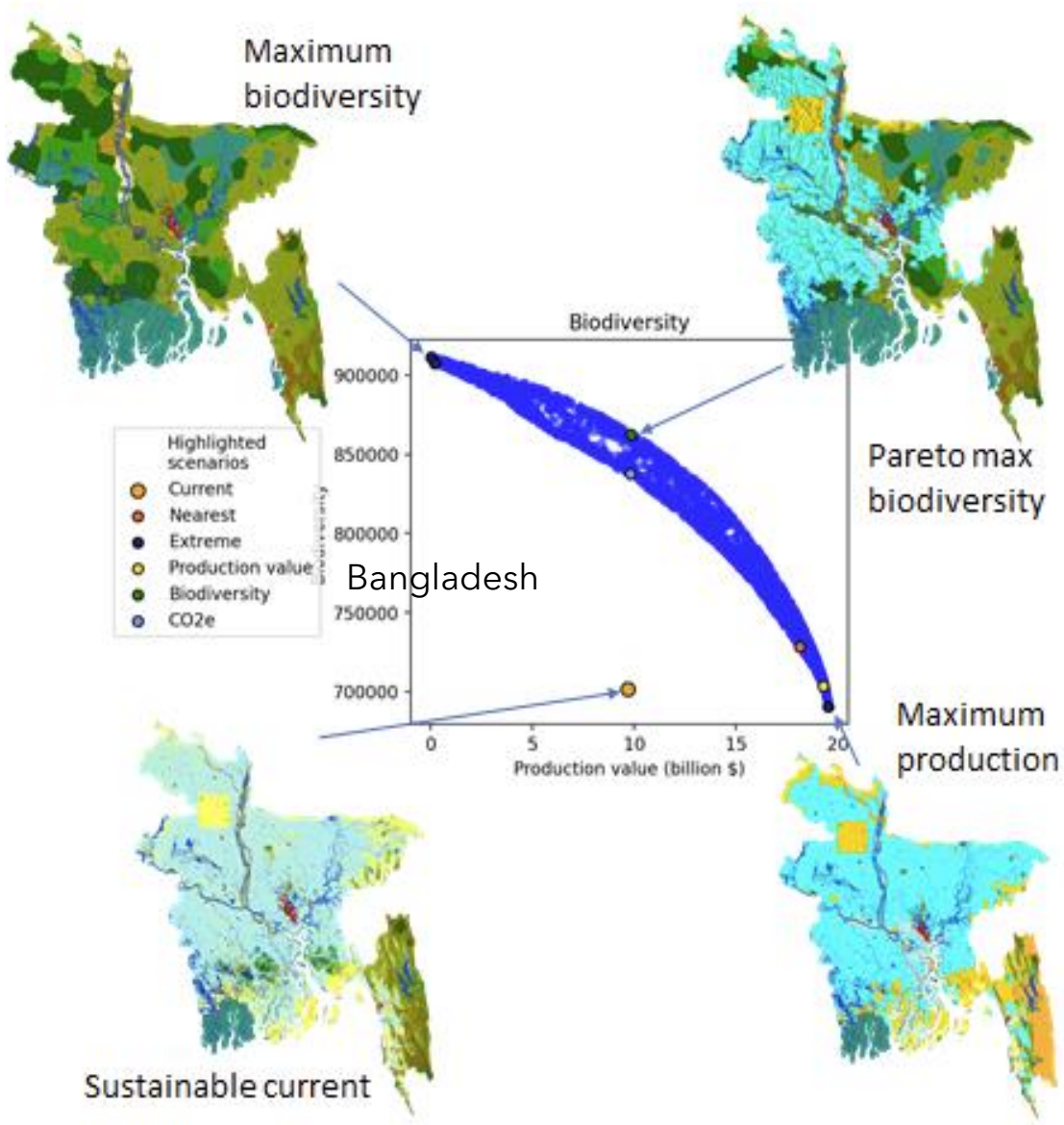
- Loss of 3 services
- Loss of 2 services
- Loss of 1 service
- No loss of services

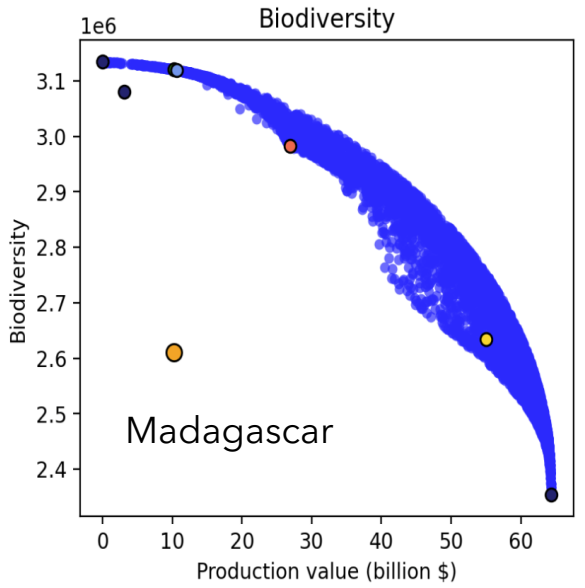


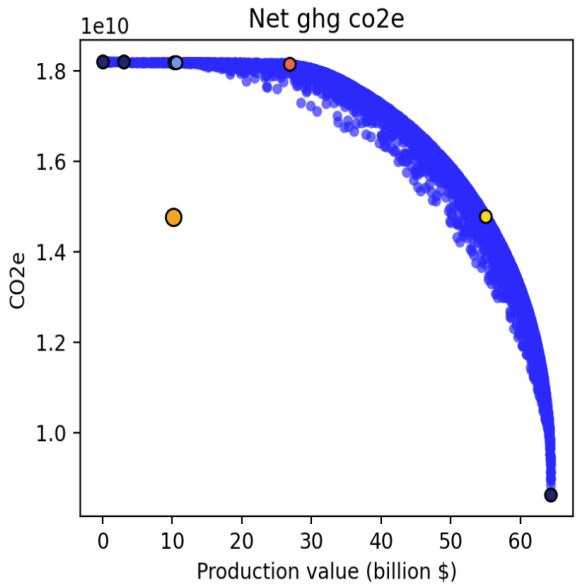
Pucallpa, Peru

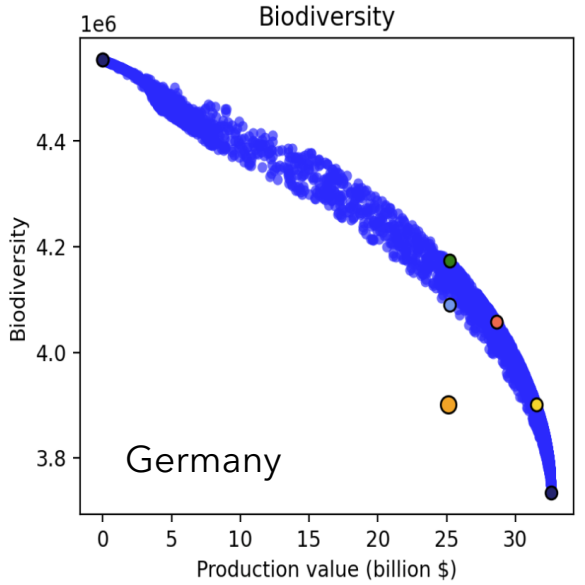


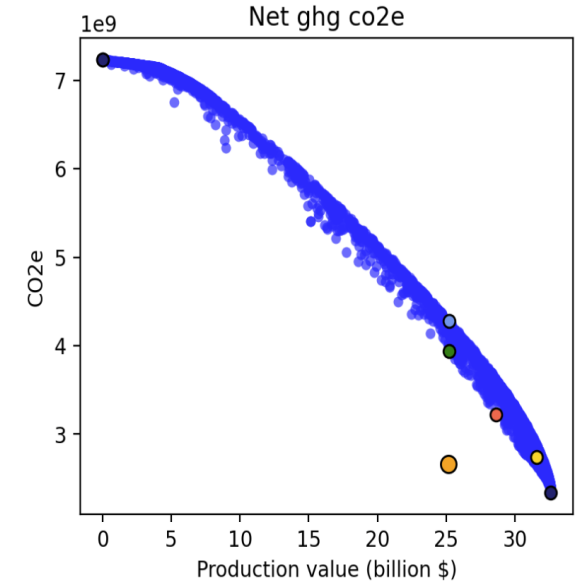
Sustainable Development through “Efficiency Frontiers”



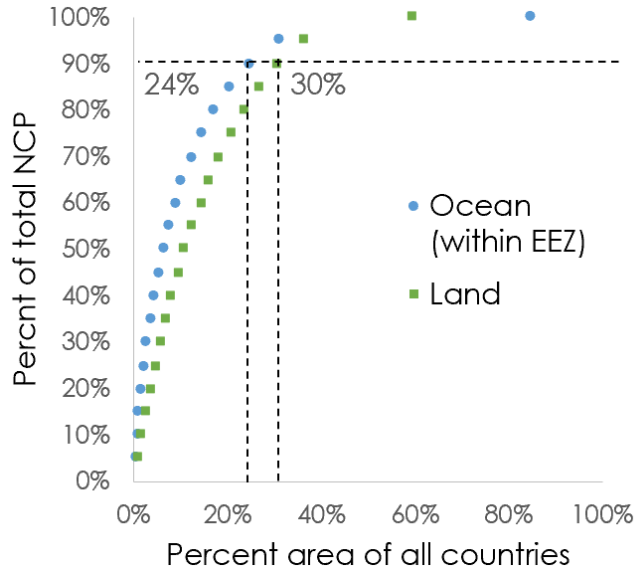








Target Setting for International Policy Negotations



Nitrogen retention
Sediment retention
Crop pollination
Fodder for livestock
Timber production
Fuelwood production
Flood regulation
Riverine fish provision
Marine fish provision
Access to nature
Marine recreation
Coastal risk reduction

Importance to Country-Level Prioritization (across 12 types of NCP)

Natural Assets

Sites Providing 90% of NCP

Critical Natural Assets

Most Important Sites (5% of NCP)

On Land

In the Ocean

Enroll in NatCap's MOOC at edx.org

Introduction to the Natural Capital Project Approach

Stockholm Resilience Centre
Sustainability Science for Biosphere Stewardship

Stockholm University

Stanford Woods Institute for the Environment

Stanford | Department of Biology

Institute on the Environment

University of Minnesota
Driven to Discover℠

The Nature Conservancy

WWF

natural capital PROJECT

bchaplin@stanford.edu

https://naturalcapitalproject.stanford.edu/

Guest Speaker: Ken Bagstad (USGS)

Interoperability & Artificial Intelligence for Ecosystem Services & Natural Capital Accounting

NASA ARSET “Evaluating Ecosystem Services with Remote Sensing” - August 2022

Ferdinando Villa, Ken Bagstad, Stefano Balbi, Alessio Bulckaen, & the ARIES Team

Interoperability:

The ability of independently developed data or tools to integrate or work together with minimal effort

A core challenge to the global SEEA community

Interoperability:

The ability of independently developed data or tools to integrate or work together with minimal effort*

A core challenge to the global NCA community

*For use in computational pipelines – models & workflows should support interoperability too

Interoperability = Common Goals & Standards

Syntactic Interoperability:

Use of compatible data formats and communication protocols.

Low bar, more limited advantages

<

Semantic Interoperability:

Data transfers where a receiving system can understand the meaning of exchanged data, reusing it appropriately.

Higher bar, greater potential for automation & data/model reuse.

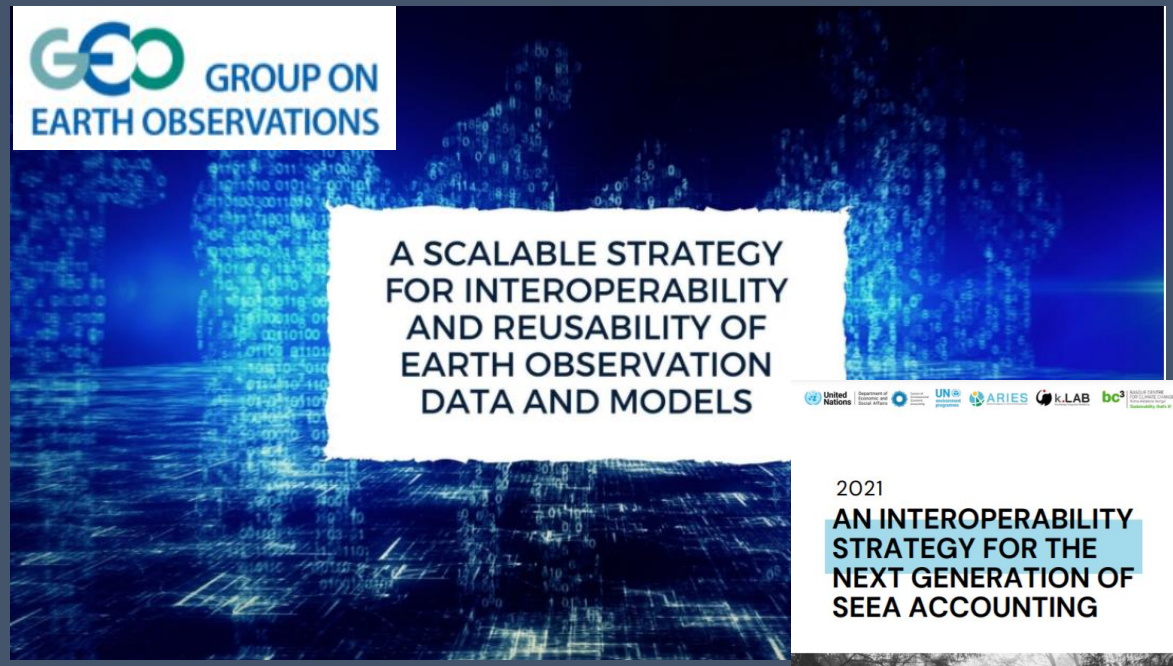
Heiler 1995

Interoperability can address serious equity issues.

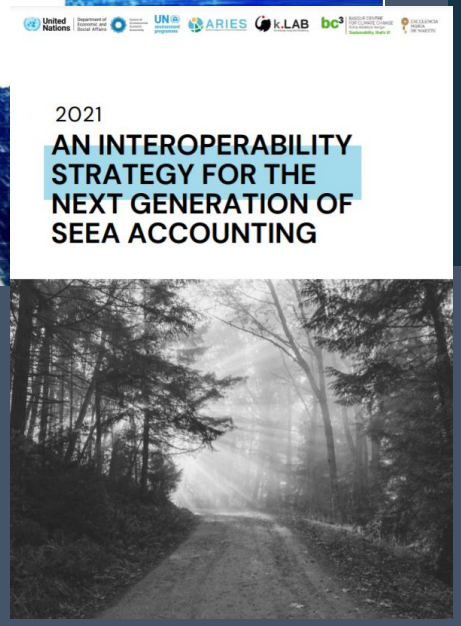
- Scientists from the Global North can do great (& painstaking) one-off studies.
- Diffusion of best scientific practices is time-consuming & requires great expertise.
- Capacity development in the Global South remains very time consuming.
- A fundamental equity issue: Global North experts are at a huge advantage. How do we maximize the opportunity for junior national government employees tasked with developing their nation's first SEEA accounts to succeed?

Before we worry about choosing a model, we need to choose a vision for the future of SEEA EA implementation.

Interoperability *must address the human element.* User-Friendly, Equitable, Community Endorsed



https://www.earthobservations.org/geo_blog_obs.php?id=527



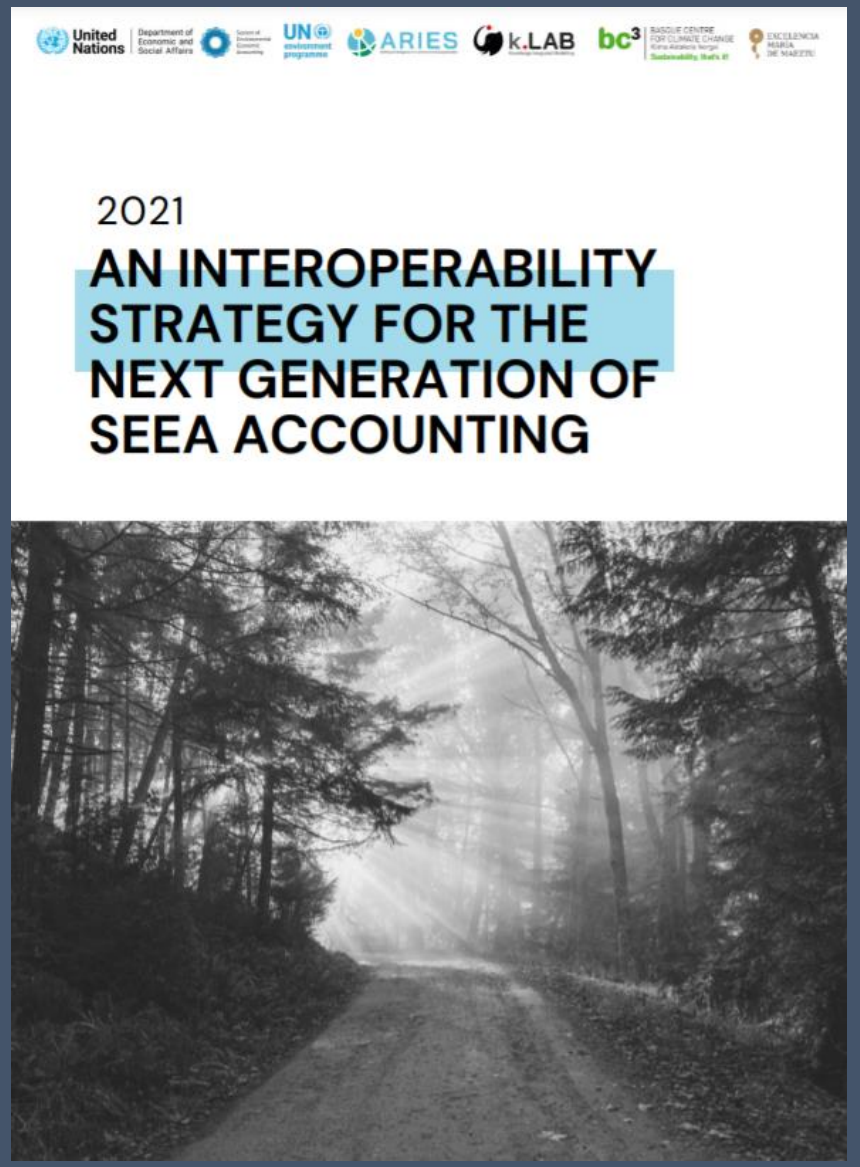
https://www.data4sdgs.org/news/why-people-are-essential-data-interoperability

A shared vision?

SEEA accounts & related indicators will be:

1. Rapidly recompilable as new science emerges,
2. Quickly produced to show the most recent trends as new annual data become available, with
3. Robust international comparisons possible from common global data, while country-specific customization is still easily done.

This vision moves high-quality, meaningful information from scientists into the hands of decision makers, the public, and the media as quickly as possible.



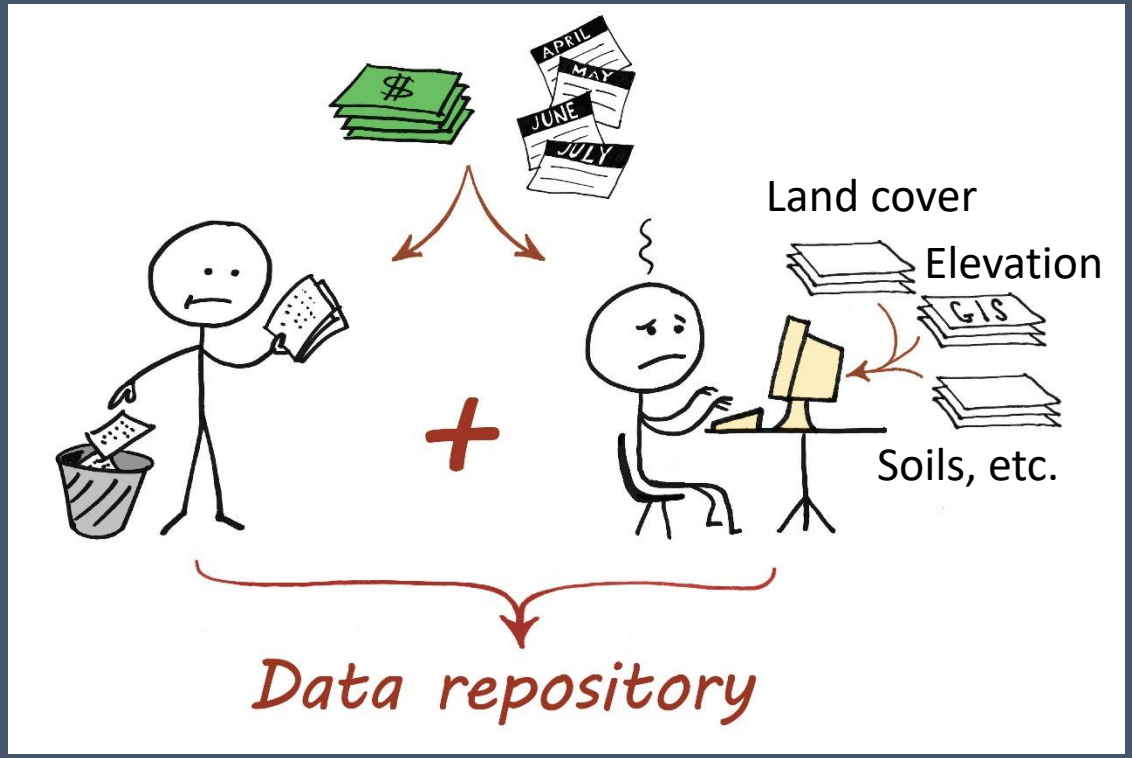
ARIES & Other Tools

- Ecosystem Service Modeling Toolkits (InVEST, ESTIMAP, LUCI, ENSYM/Data4Nature): Provide a set of models, one for each ES
- Data Viewers (UN Biodiversity Lab): Visualize data in interactive, attractive settings
- Cloud Computing Platforms (Google Earth Engine, Microsoft Planetary Computer): Run large-scale computations on the cloud
- Model integration frameworks (CSMDS, VLab, OpenGMS): Highly technical tools for model coupling, usually using syntactic interoperability

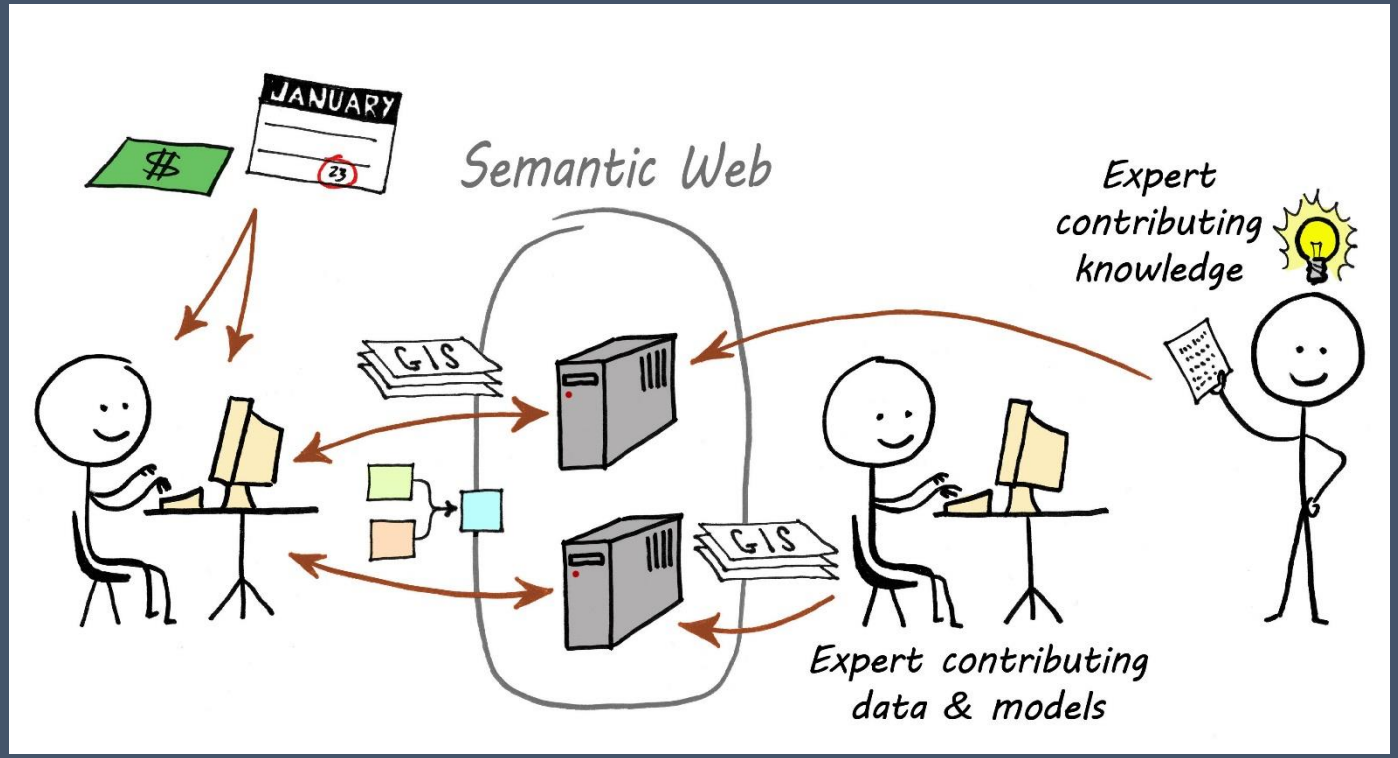
ARIES: Assemble & use (with AI support) collective knowledge of the scientific community to make it easier to implement SEEA globally

ARIES Example: Sediment Retention Accounting

Revised Universal Soil Loss Equation (RUSLE): Commonly used in InVEST, LUCI, ARIES, and one-off modeling applications



Status Quo



Semantic Interoperability in ARIES for SEEA

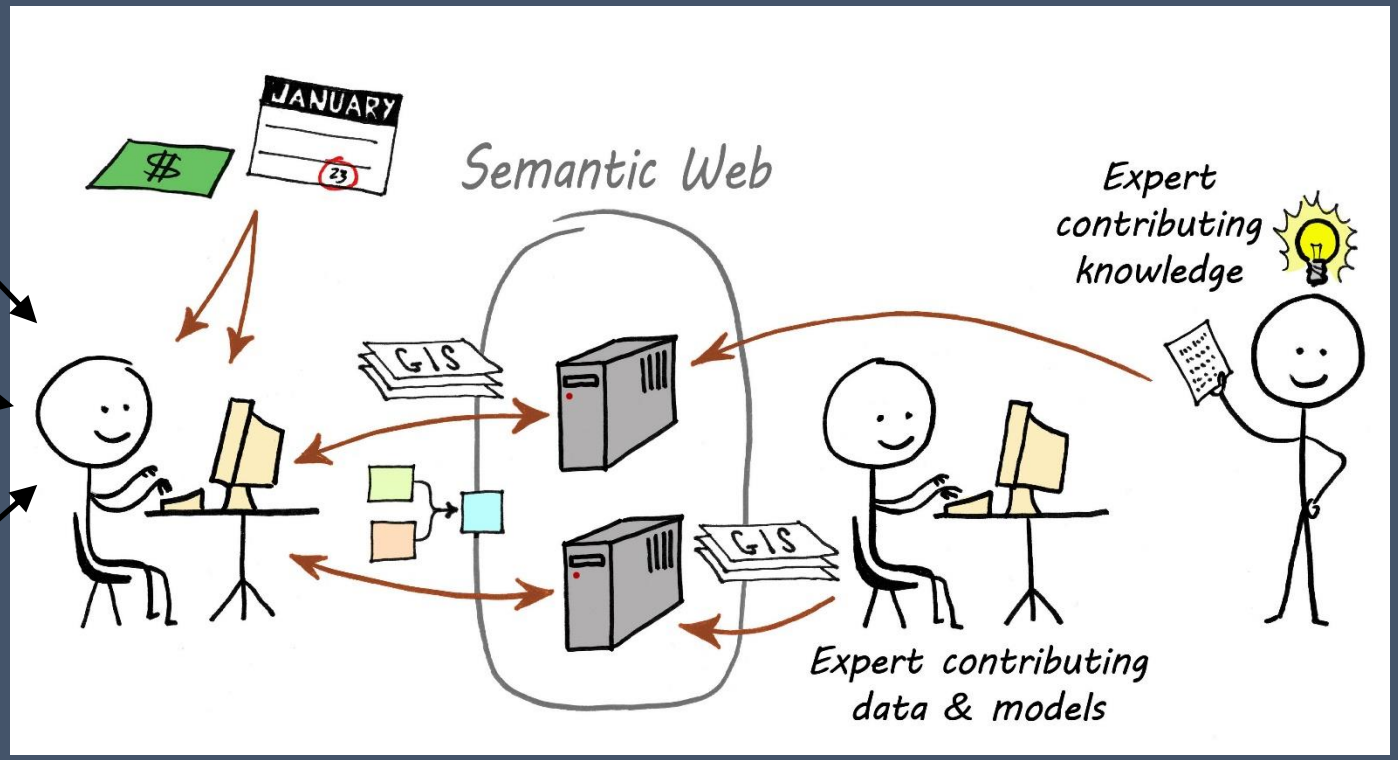
Given the urgency of scaling up SEEA, interoperability is a powerful tool to do so *as a community.*

Who benefits?

An ecosystem accounts compiler

A member of an indigenous community or urban environmental justice group

A small NGO or local government

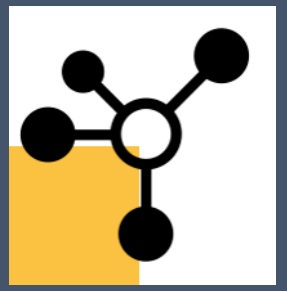


Support of ARIES for SEEA

- Wiki Space (accessible with your username & password; register at https://integratedmodelling.org/hub/): https://confluence.integratedmodelling.org/
  - Questions: https://confluence.integratedmodelling.org/questions
  - Modeling Quick Tips: https://confluence.integratedmodelling.org/display/KIM/0.+Getting+started
- Software Support: support@integratedmodelling.org

Support from the ARIES Team

1. Training Materials (video, in-person, remote)



2. Support for Data Hosting (pending QGIS plugin for data ingestion)

3. Support for Semantic Annotation of Data & Models

How can national governments use ARIES for SEEA?

1. Determine which methods to endorse for use for SEEA accounting
2. Catalog available national data & models for SEEA; determine which can be made public and which are restricted
3. Make needed data & models interoperable with ARIES, placing in public or private projects as appropriate
4. Test & validate models
5. Produce accounts using ARIES for SEEA
    1. Revisit underlying data & methods as improved approaches become available

A Global South NCA Vision – By 2027, with a clear focus on interoperability from the Global South nations will:

- Produce their own SEEA EA accounts, endorsed by their National statistical offices & populated with their own data
- Regularly update accounts as new global, regional, and national data become available
- Continually improve the quality of estimates as science continues to evolve
- Lead South-South capacity building around NCA

Discussion/Q&A

Debunking Interoperability Myths

1. “I have better data & models for my part of the world than are available in your system.”
2. “The status quo will work to integrate scientific knowledge for SEEA.”
3. “There’s value in taking lots of time to get to know each individual dataset and every aspect of a model.”
4. “We can’t trust inexperienced users with ARIES.”
5. “We’ll never maintain quality control.”
6. “Tomorrow, we’ll be advocating for common use of a different, more advanced platform.”

ARIES is a complex system for science integration, focused on SEEA. It’s easy to misunderstand. We need to move forward from a common understanding.

ARIES Myth #1

"I have better data & models for my part of the world than are available in your system."

Corollary 1: "ARIES is only useful for developing countries with limited data/scientific capacity." (Not true as better data/models are made interoperable.)

Corollary 2: "ARIES is rigid and prescriptive, forcing the use of a particular dataset/model." (The exact opposite is true.)

Certainly true. But, if you add your data and models to an interoperable system, they can be used by a wider audience to more quickly generate policy-relevant results (interoperable data & models are more useful).

Machine Reasoning: How can a machine pick the "best" data/model under which circumstances?

Initial prioritization, adjustable by advanced users; role for ML in prioritization:

1. Lexical Scope (How "close" are the data/model to the namespace & project, within k.LAB repositories)
2. Trait Concordance (Models with more shared attributes to the requested concept prioritized)
3. Semantic Distance (Concrete models prioritized over abstract ones)
4. Time Specificity (Closest temporal match to the user query is selected)
5. Time Coverage (Models with more complete temporal coverage are prioritized)
6. Space Specificity (Local models chosen over national, over global)
7. Space Coverage (Models with more complete spatial coverage are prioritized)
8. Inherency (Models specified for location/scale-specific use prioritized over generalized models)
9. Evidence (Data models prioritized over computed models)
10. Network Remoteness (Local models prioritized over those from distant networks)
11. Scale Coherency (Number of domains shared with the contexts)
12. Subjective Concordance (User-specified metadata & weightings)

Roles of Key Stakeholders:
Data Providers (NSOs, Science Agencies, Academic Scientists)

1. Expose & maintain key spatial datasets as Open Geospatial Consortium services using networked infrastructure - hosted independently, through the U.N. Global Platform, or other networks explicitly designed for semantic interoperability
2. Use standard coordinate resource systems (projections) that enable on-the-fly reprojection
3. Use open, widely available standards & complete, correct, semantically meaningful metadata; provide an Application Programming Interface (API)
4. Produce Uniform Resource Name (URN)-specified resources from each dataset & publish to a networked node to enable later semantic annotation
5. Use & collaboratively develop common ontologies & vocabularies (allows people & computers to know when data & model components are interchangeable)
6. Identify a point of contact from each institution to follow semantics development & be responsible for their consistent use
7. As a community, gradually move the semantic annotation task to data producers (requires best practice documents, handbooks for specific problem areas, ad-hoc tooling)

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Machine Actionable

+

Semantically Meaningful

Key Building Blocks for Interoperability

1. Semantics: A flexible, shareable, easy-to-learn **language** to describe scientific observations.

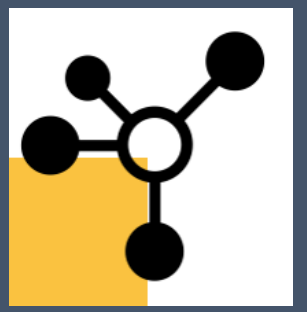
Developed by experts in collaboration with disciplinary scientists – typical scientist/NSO does *not* build these.

Use to accurately describe data & model elements in a consistent, machine-readable way.

2. Open, Linkable Data: Enabling access & publishing of semantically annotated data.

Put data on the web in machine-accessible formats.

Best practices already exist: no more PDFs of model parameters or zip files of spatial data.



3. Open, Linkable Models: Open, accurate, "Wikipedia-like" sharing and linking of models.

Code models in a modular style that facilitates reuse (vs. monoliths).

Build documentation into code for automated reporting.

Specify appropriate conditions for safe reuse of your models.

Where should we invest our efforts?

Major Needs for Interoperability

- Consensus & understanding of the need
- Cross-platform, machine actionable data & models
- Semantics (metadata descriptors) that can be navigated by AI to assemble data & models
- Eliminate hidden costs (cloud egress costs, restrictions on private-sector use)

Balbi *et al. Environmental Evidence* (2022) 11:5
https://doi.org/10.1186/s13750-022-00258-y

Environmental Evidence

COMMENTARY Open Access

The global environmental agenda urgently needs a semantic web of knowledge

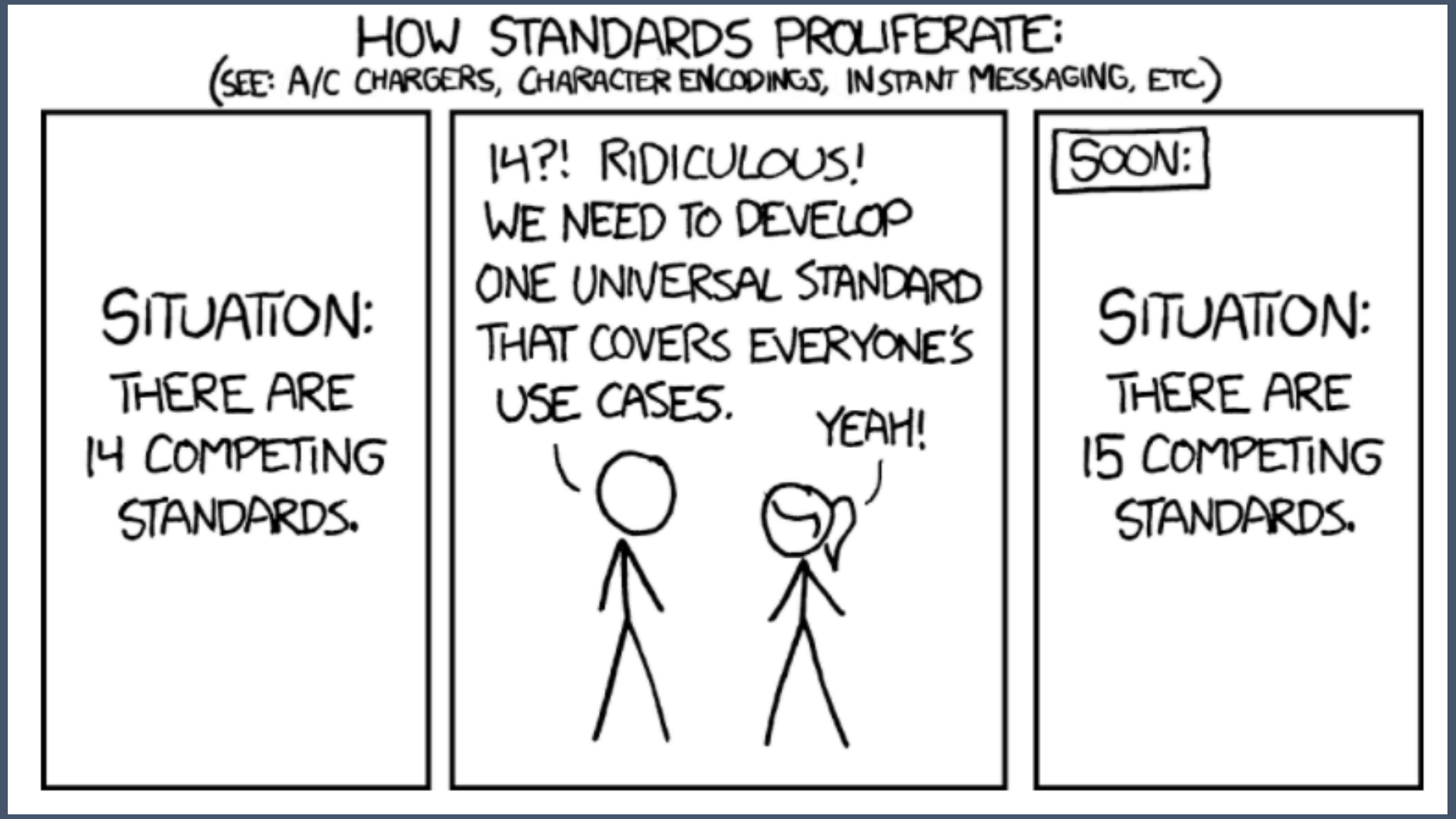
Stefano Balbi[1,2*], Kenneth J. Bagstad[3], Ainhoa Magrach[1,2], Maria Jose Sanz[1,2], Naikoa Aguilar-Amuchastegui[4], Carlo Giupponi[5] and Ferdinando Villa[1,2]

Next Steps for Interoperable SEEA Data & Models

1. Pilot Testing
2. Engaging Key Stakeholders (your organizations & others)
3. Governance
4. Training & Capacity Building

With a *shared vision,*
using *common standards*
to *serve the SEEA community's needs*

Common ground is needed!



https://xkcd.com/927/

Summary

- Remote sensing can be used to assess a variety of questions related to the valuation of ecosystems services.
- There are many types of models and methods for assessing the value of ecosystem services.
- The Natural Capital Project aims to improve the well-being of people and our planet by motivating targeted investments in nature
  - Science, technology, partnerships
- The ARIES technology highlights interoperability:
  - To allow models and data to be contributed by independent researchers, hosted on a network, and automatically assembled into model workflows
- Next Session: Ecosystem Accounting Use Cases
  - Guest Speaker: Mehdi Heris (Hunter College City University of New York)

Contacts

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@NASAARSET

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  - Juan Torres-Pérez: juan.l.torresperez@nasa.gov
- Training Webpage:
  - https://appliedsciences.nasa.gov/join-mission/training/english/arset-evaluating-ecosystem-services-remote-sensing

Check out our sister programs:


APPLIED REMOTE SENSING TRAINING PROGRAM
TRAIN - EMPOWER - ADVANCE

Thank You!