Integrating Ecosystem Services into Decision Making: The Natural Capital Approach & Tools

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Outline

Why use a natural capital approach?

What is InVEST?

Example: Impact and mitigation of road development

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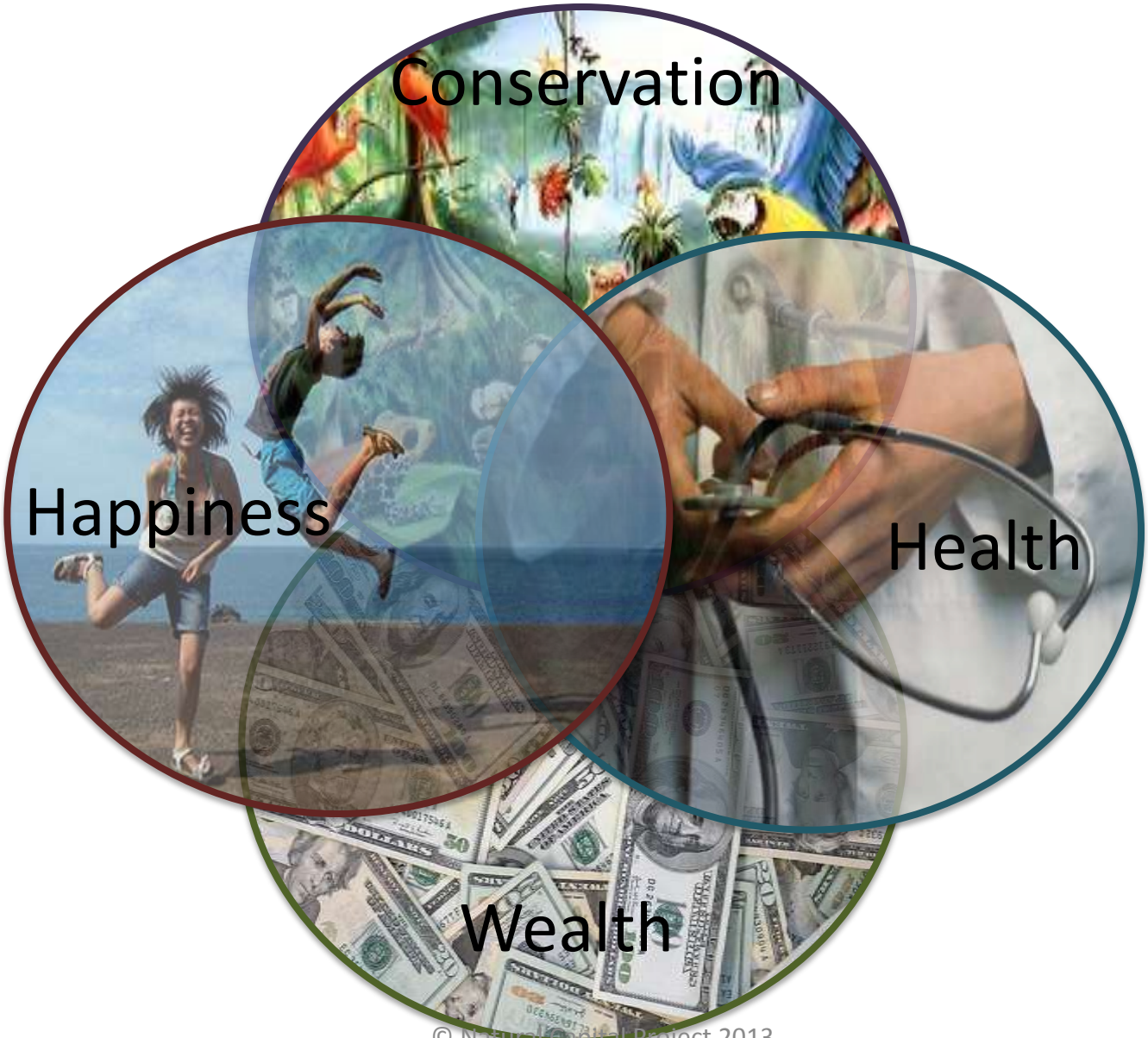
What is InVEST?

Example: Impact and mitigation of road development

Nature supports us in countless ways

Ecosystem services link nature & human welfare

Ecosystem services make trade-offs apparent



Effects of management decisions

lbs of fish $?

# of species protected ?!

MW of hydro power $?

$? # jobs, board feet of timber

Effects of management decisions

lbs of fish

ecosystem health

# of people mangroves protect

# of tourists

Why assess ecosystem services?

more comprehensive accounting of impacts

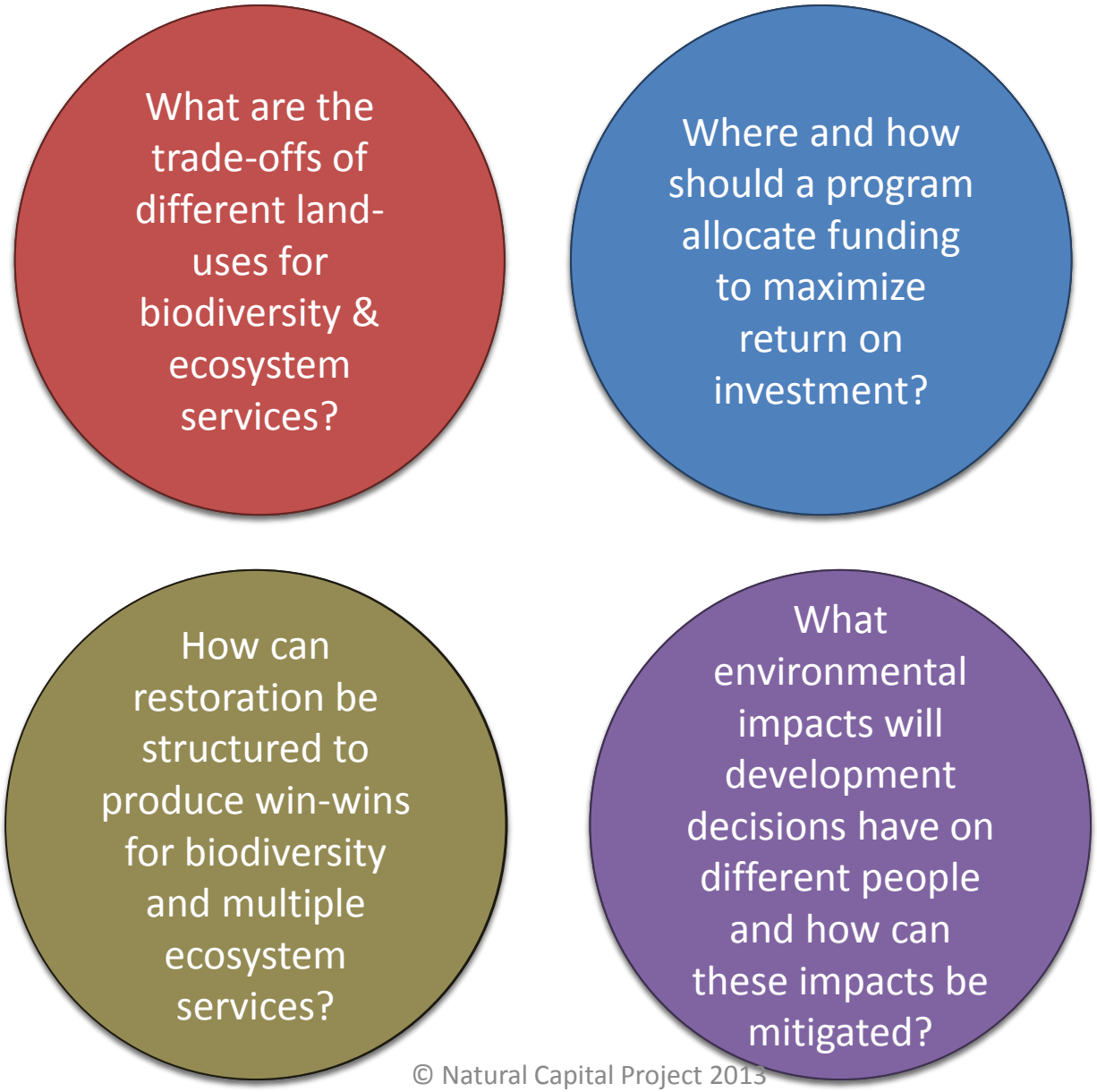
generate financing for conservation

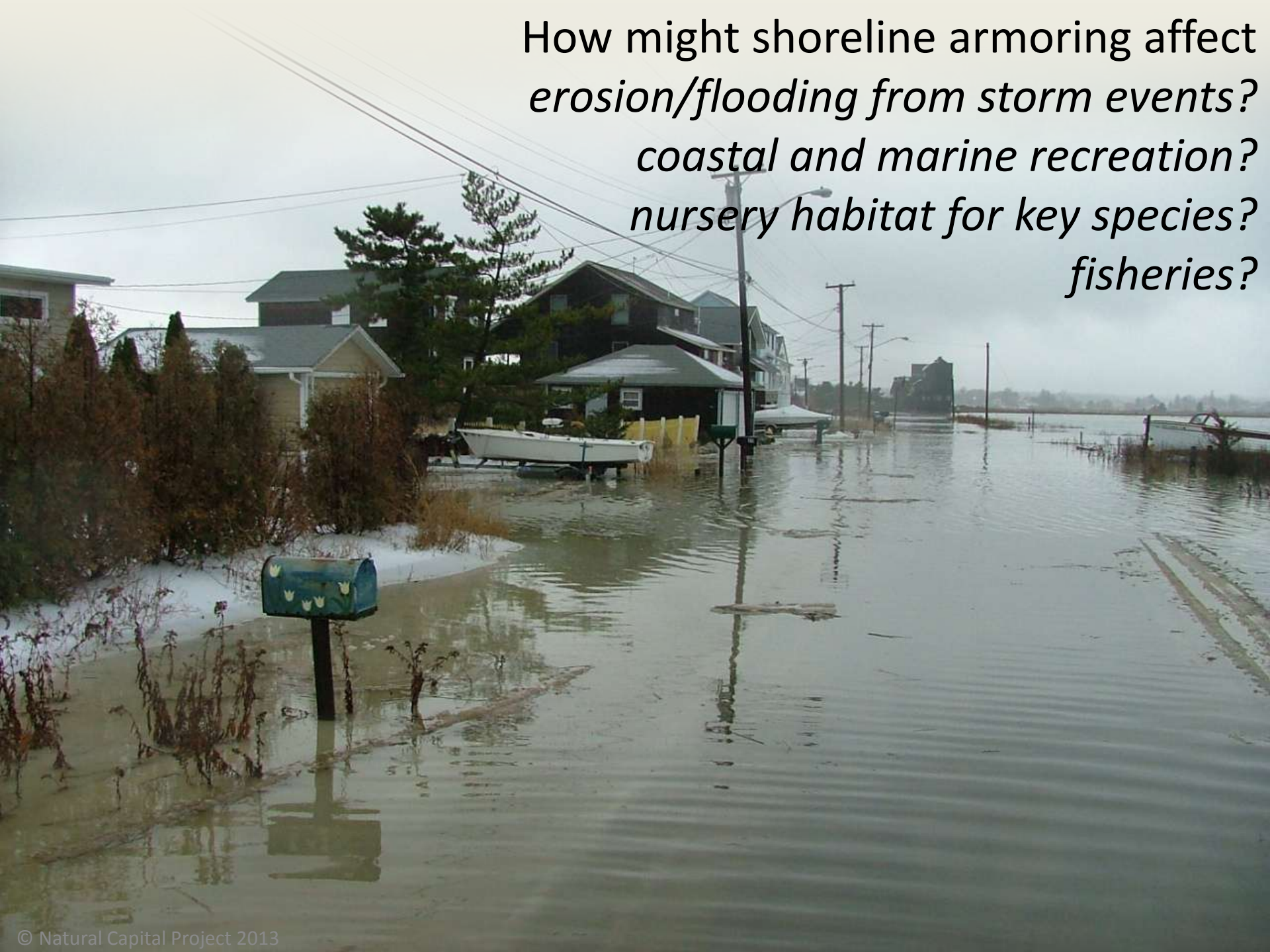
innovative policy mechanisms

engage a wider array of stakeholders

important for human wellbeing and prosperity

Decision ontexts





How might shoreline armoring affect

erosion/flooding from storm events?

coastal and marine recreation?

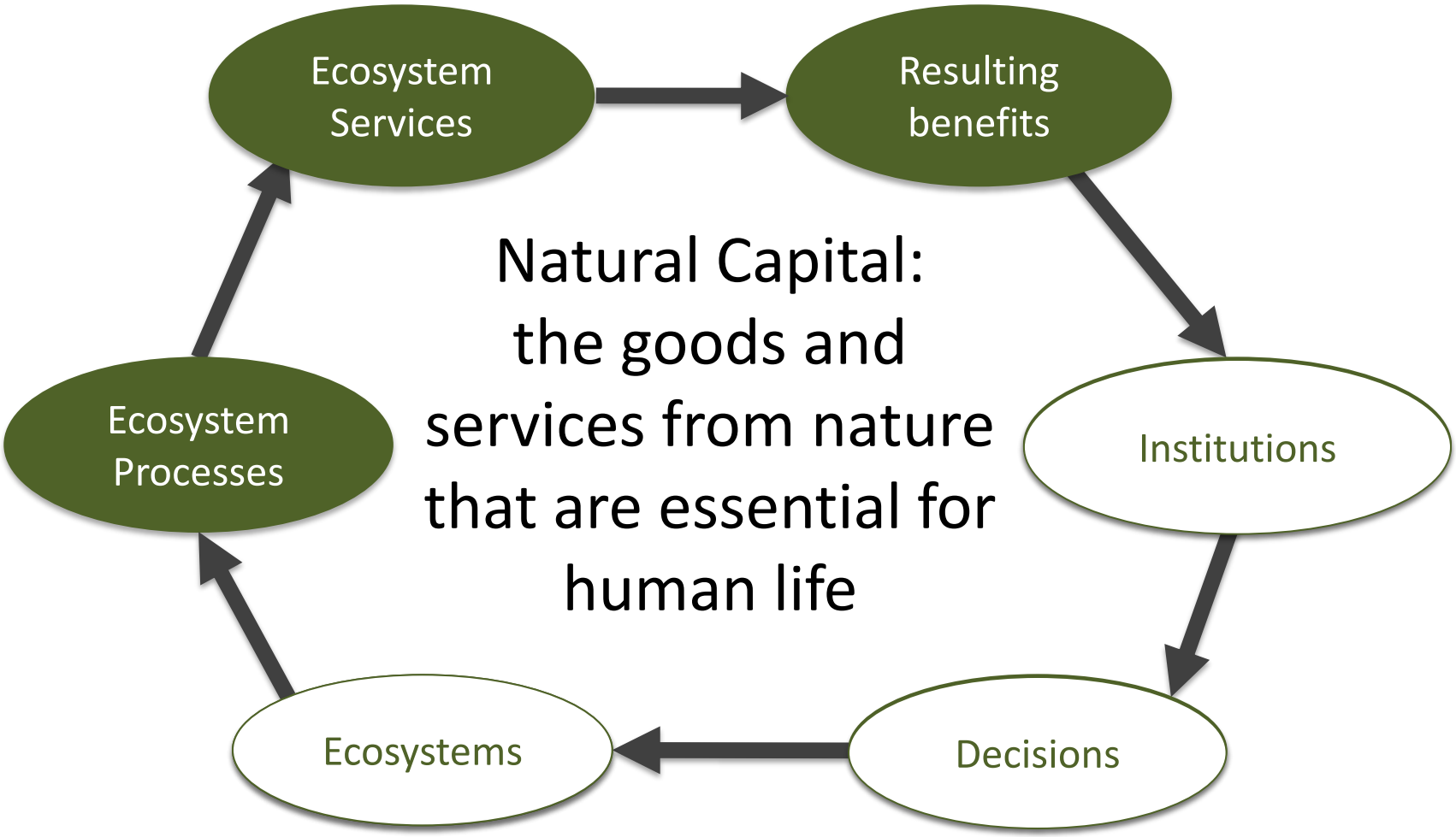
nursery habitat for key species?

fisheries?

Where can we place protected areas or other conservation actions to maximize biodiversity as well as

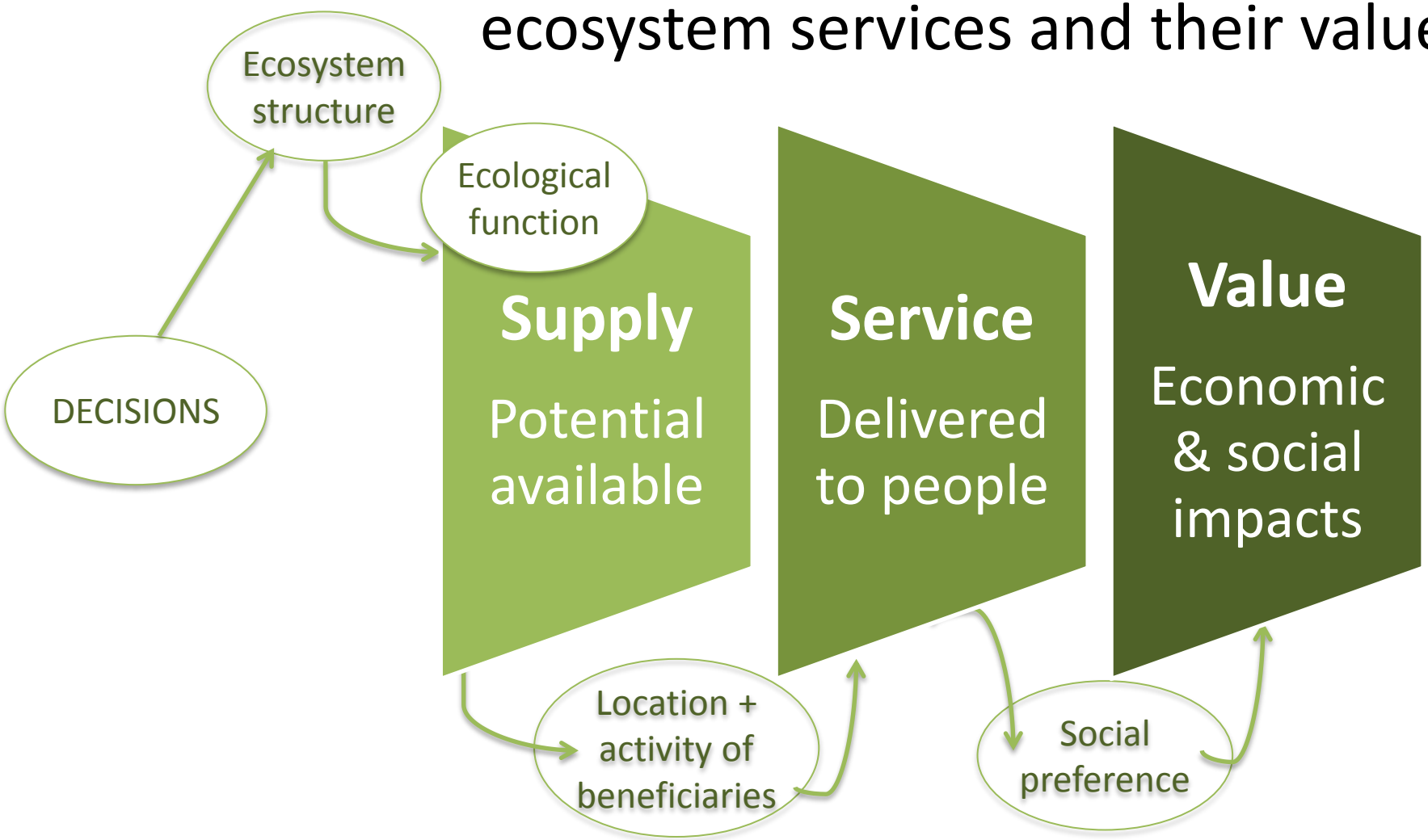
water purification
flood mitigation
pollination
irrigation
carbon sequestration
and *tourism?*

Natural capital in decision-making



The Natural Capital Approach

Changes in ecosystems → Changes in ecosystem services and their values



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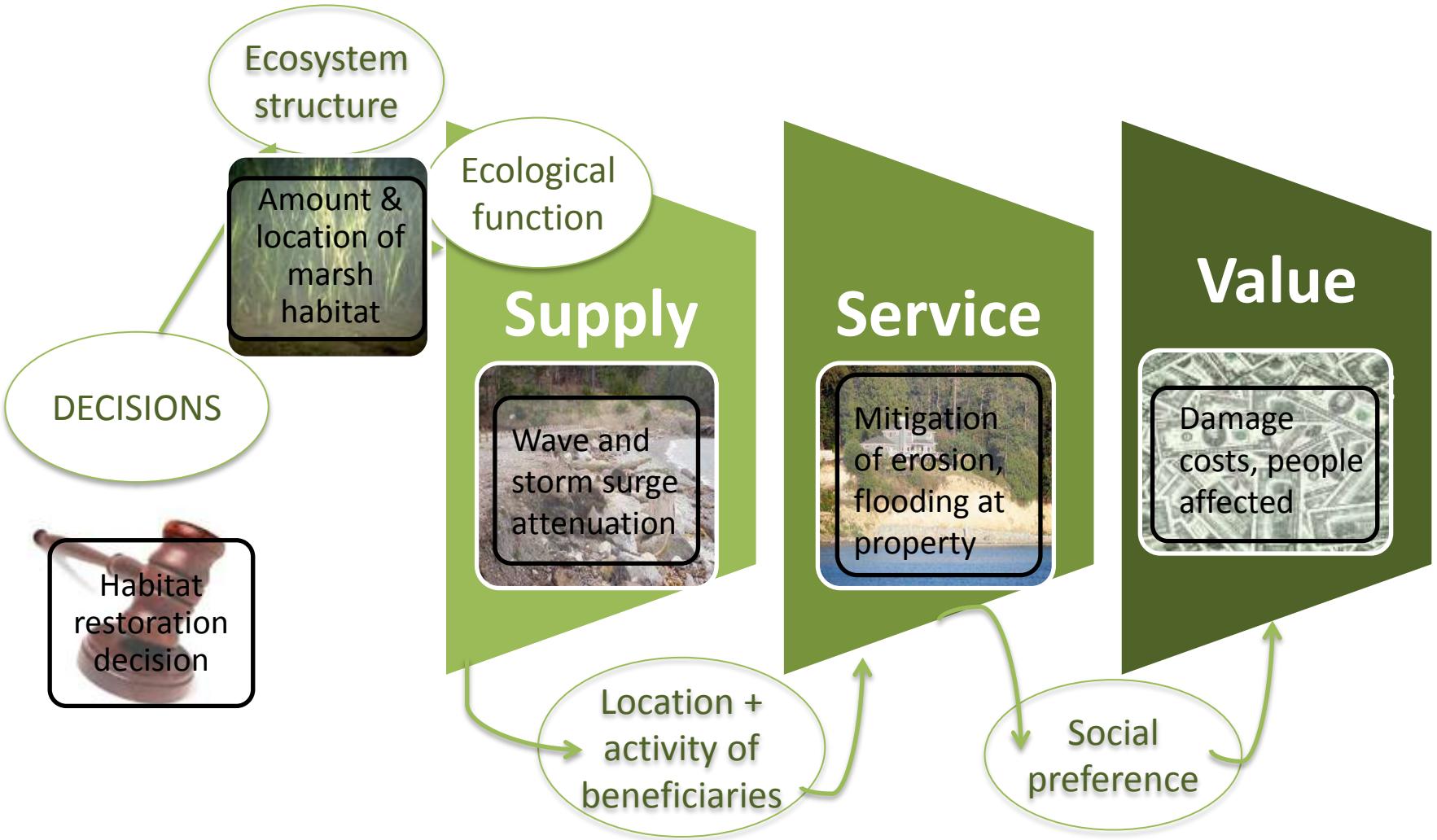
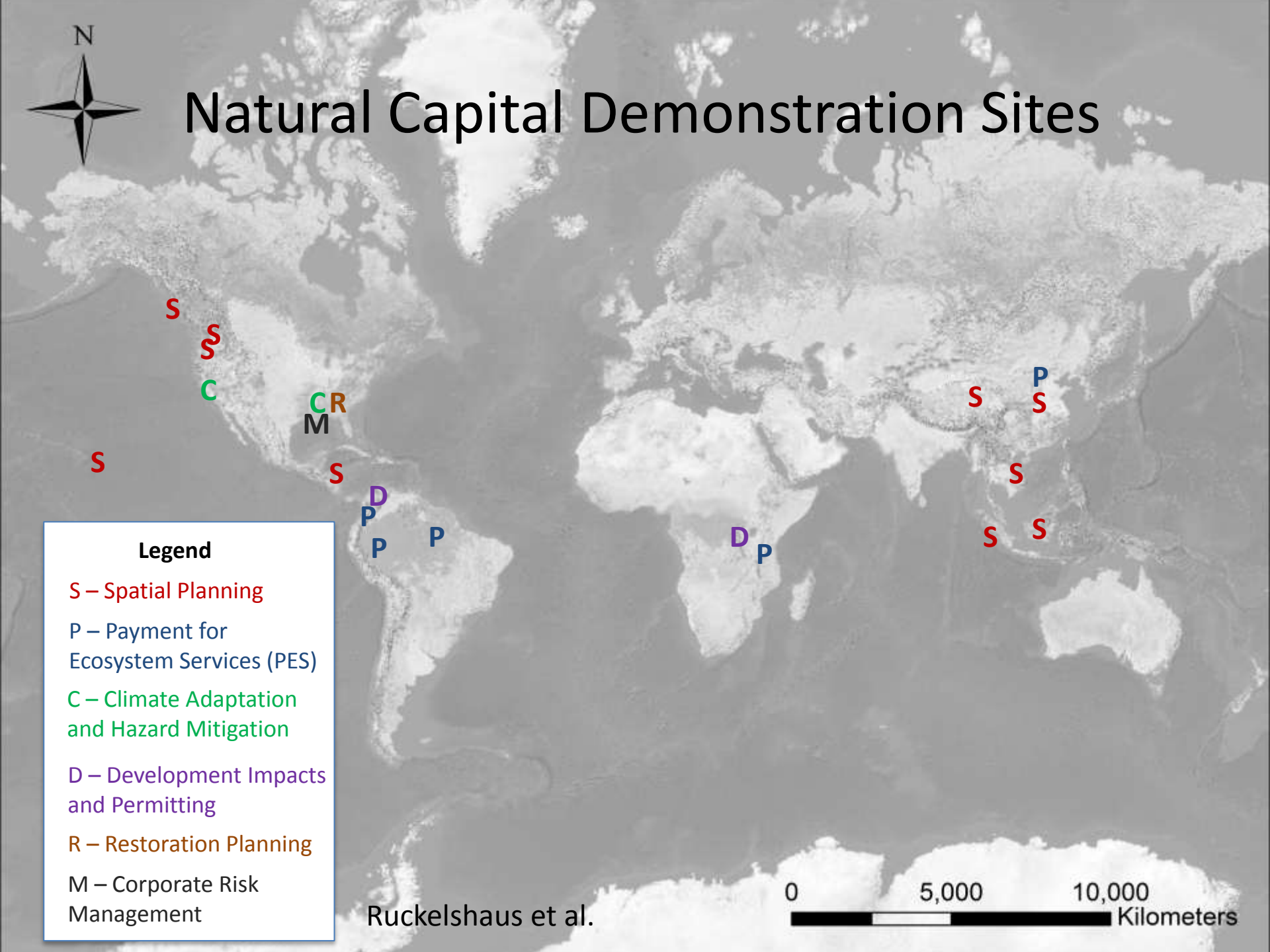



N
Natural Capital Demonstration Sites
S
S
S
C
C
R
M
S
S
D
P
P
P
D
P
P
S
S
S
S
S
Legend
S – Spatial Planning
P – Payment for Ecosystem Services (PES)
C – Climate Adaptation and Hazard Mitigation
D – Development Impacts and Permitting
R – Restoration Planning
M – Corporate Risk Management
Ruckelshaus et al.
0
5,000
10,000
Kilometers

Outline

Why use a natural capital approach?

What is InVEST?

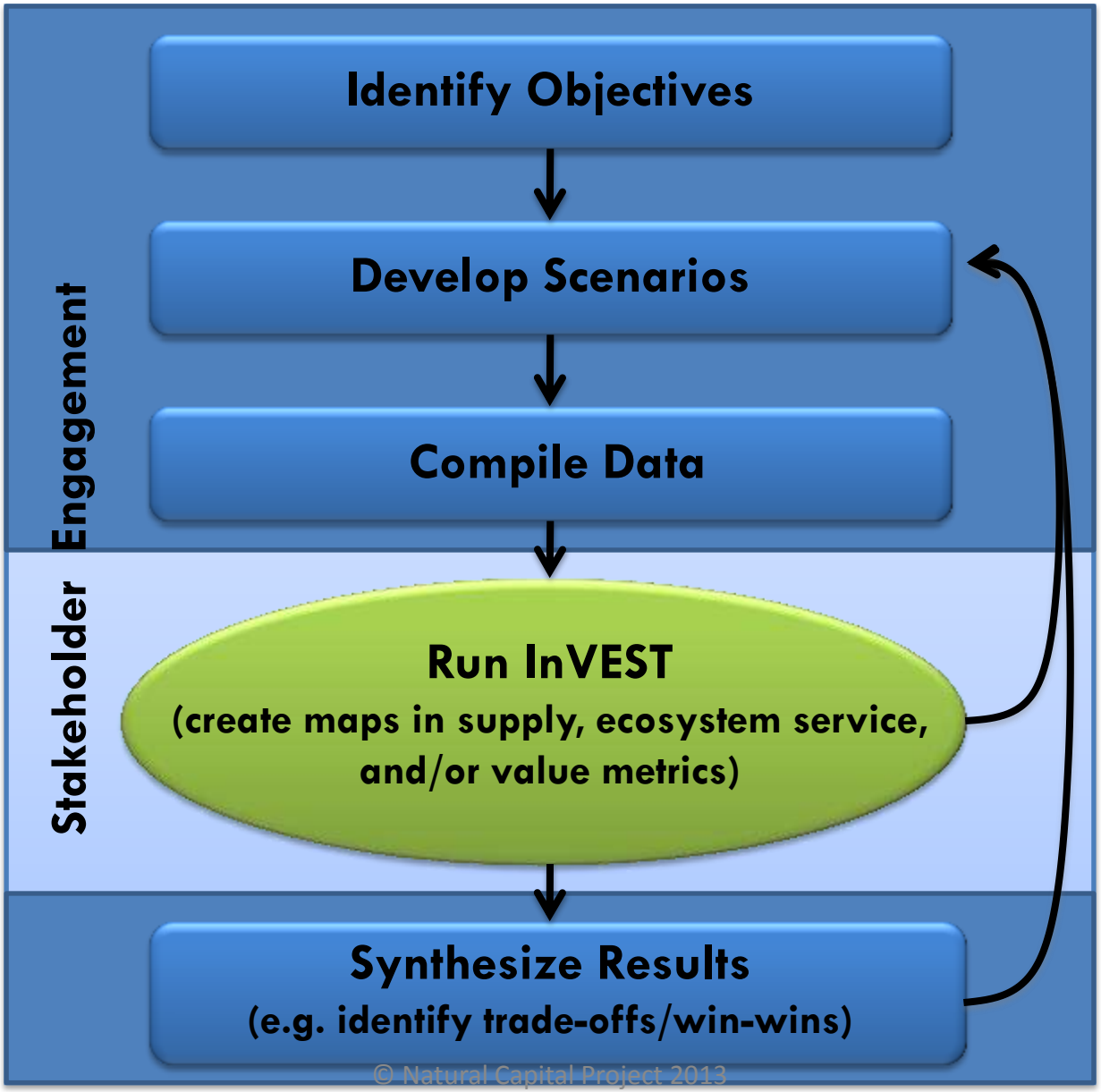
Example: Impact and mitigation of road development

InVEST

integrated valuation of environmental services and tradeoffs

InVEST
integrated valuation of environmental services and tradeoffs

One piece of the approach



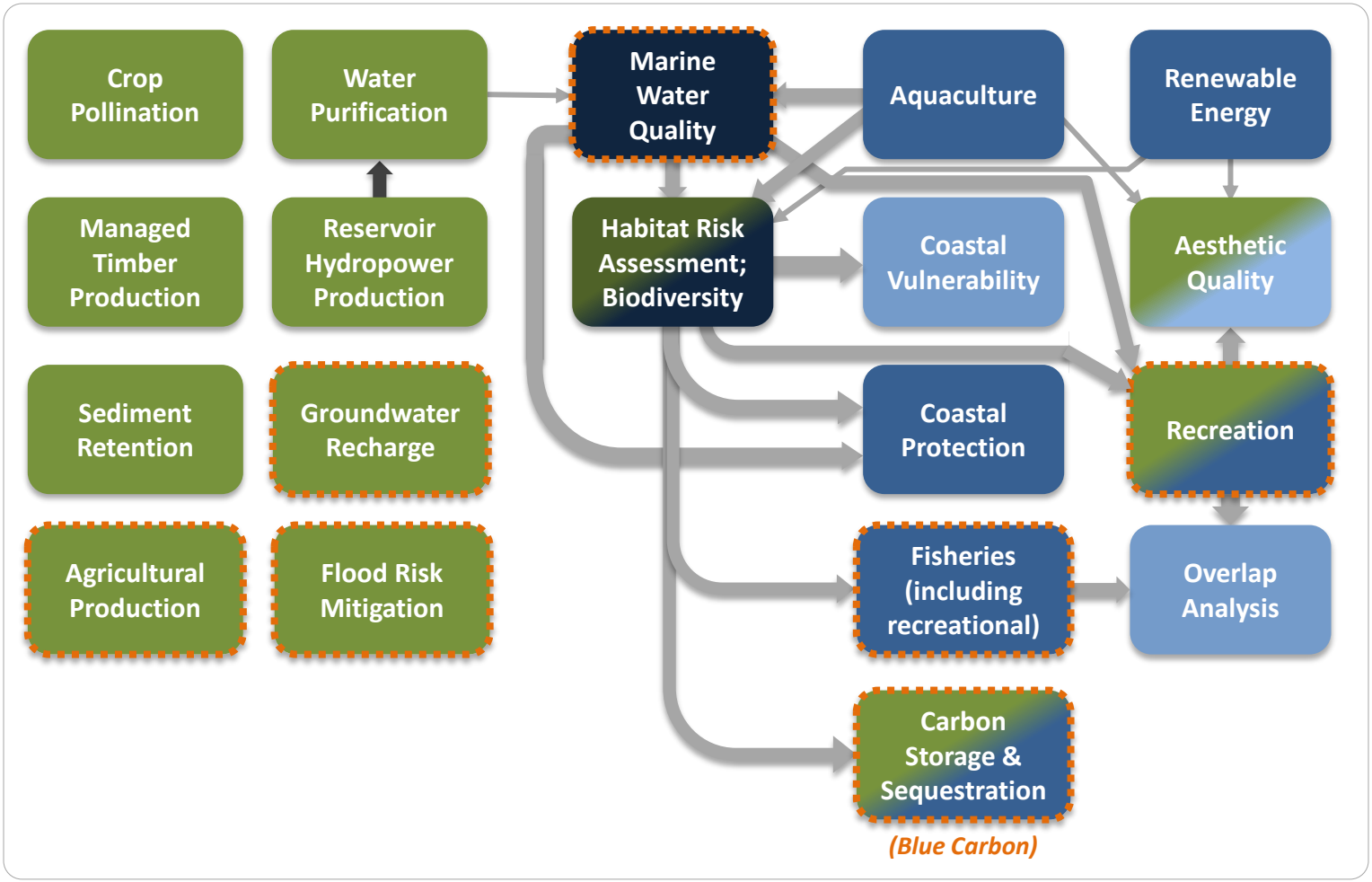
InVEST
integrated valuation of environmental services and tradeoffs

InVEST

Quantify, map and value the benefits provided by terrestrial, freshwater and marine systems

Open source | Flexible | Soon ArcGIS independent!

InVEST Models & Linkages



Terrestrial/freshwater model: Tier 1 supporting service

Terrestrial/freshwater model: Tier 1 that quantifies service

Marine model: Tier 1 supporting service

Marine model: Tier 1 that quantifies service

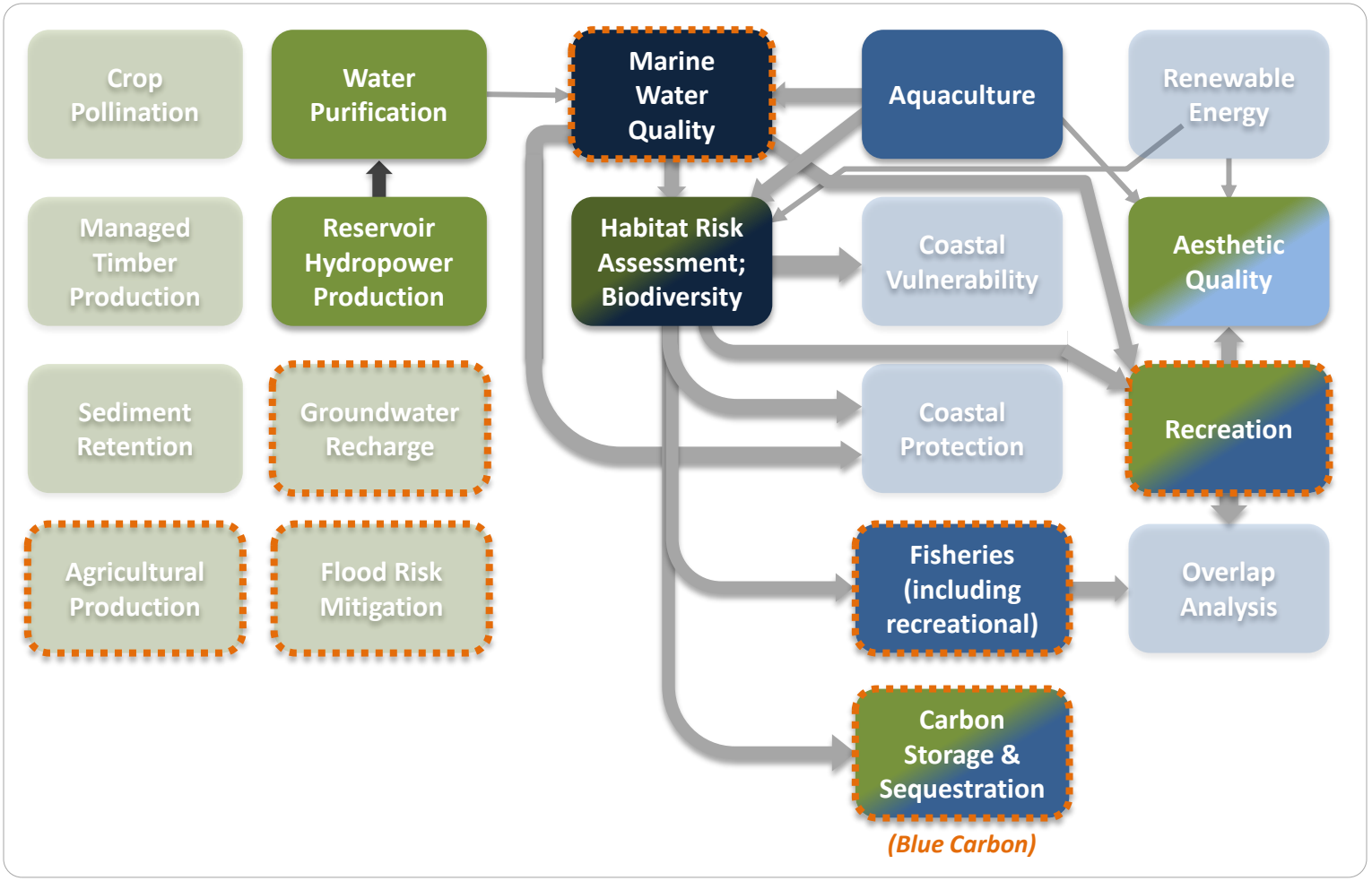
Marine model: Tier 0

Model coming soon!

Optional model linkage, no sequencing

Required/optional model linkage, sequencing needed

InVEST Models & Linkages



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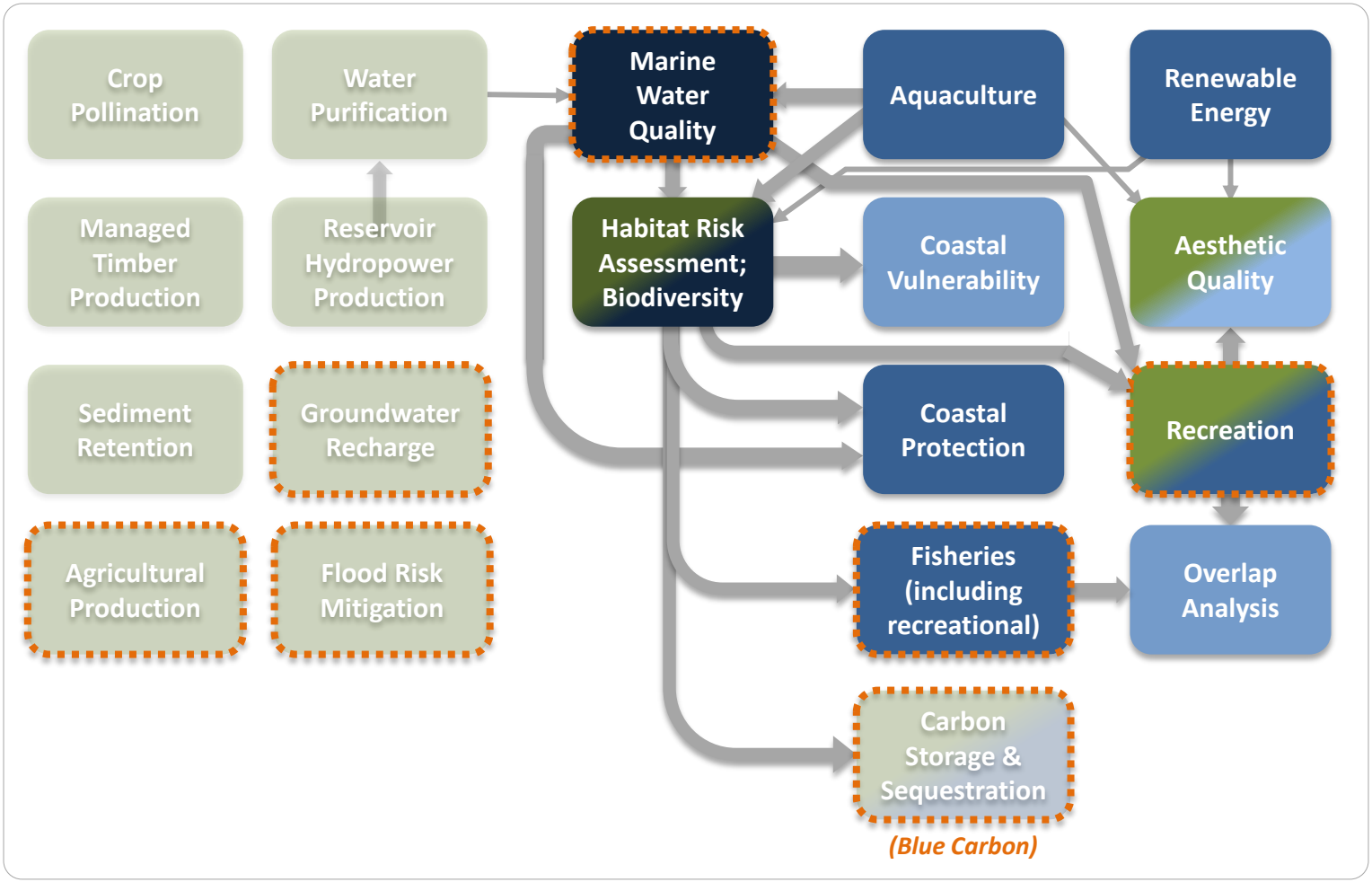

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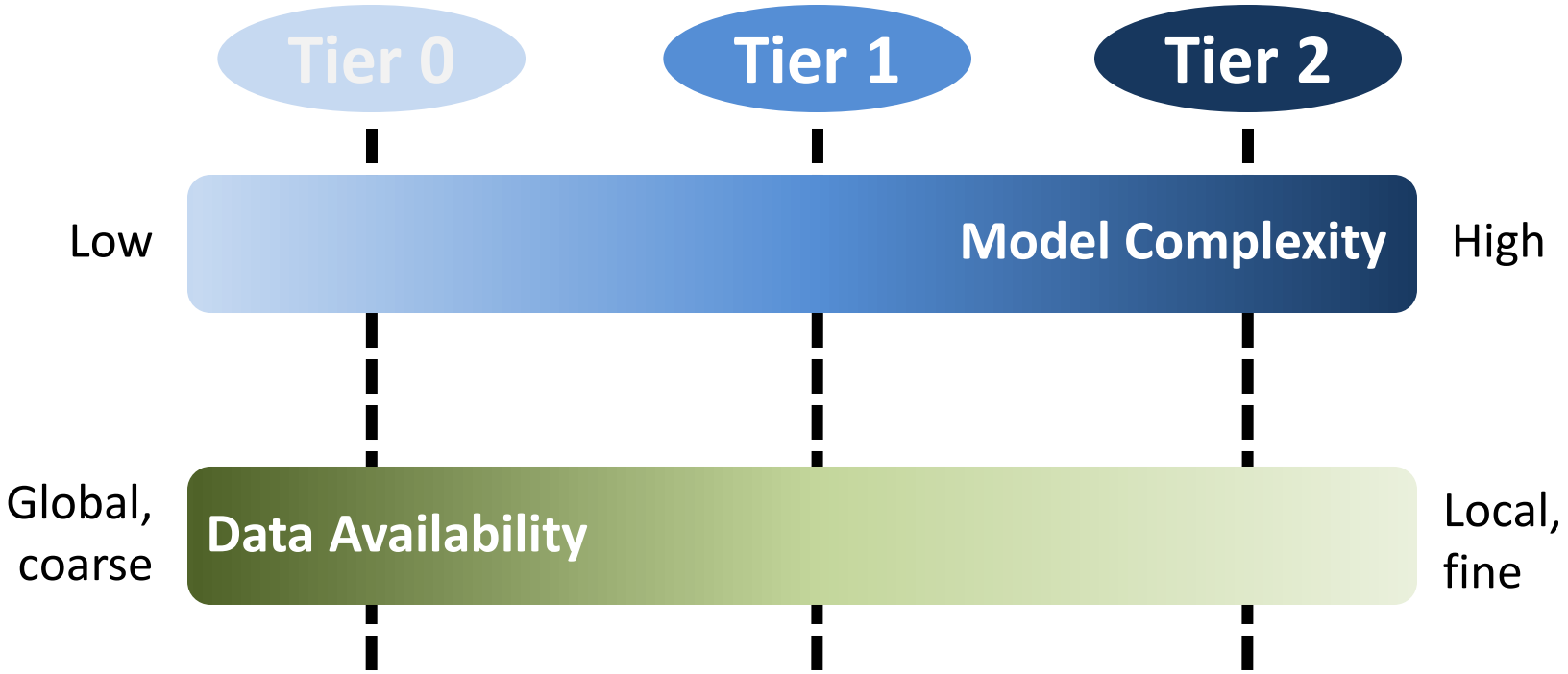
integrated valuation of environmental services and tradeoffs

A tiered approach



- Relative amounts
- No valuation
- Not time-specific, or annual average

- Absolute amounts
- Valuation
- Annual average, no temporal dynamics

- Absolute amounts
- Valuation
- Daily to monthly time step, some temporal dynamics

InVEST
integrated valuation of environmental services and tradeoffs

Model inputs

Spatial data

Land use/ Land cover

Soil type

Topography

Cities

Infrastructure

Associated data

E.g.:

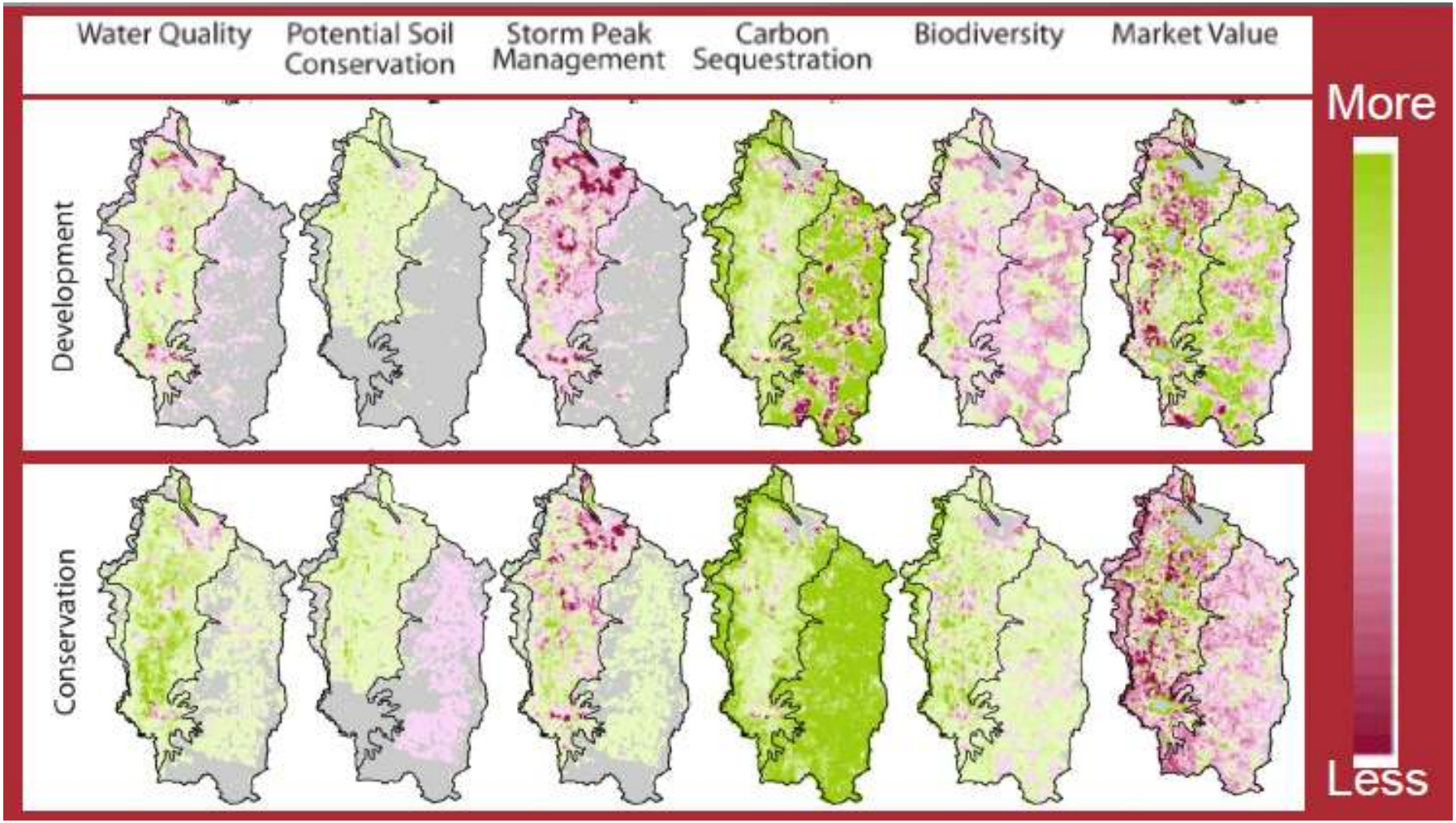
- Carbon pools by land use/land cover and soil
- Habitat suitability by land use/land cover
- Market value of timber or carbon

InVEST
integrated valuation of environmental services and tradeoffs

Outputs: quantifying & mapping

Relative or absolute measures

Biophysical amount or value

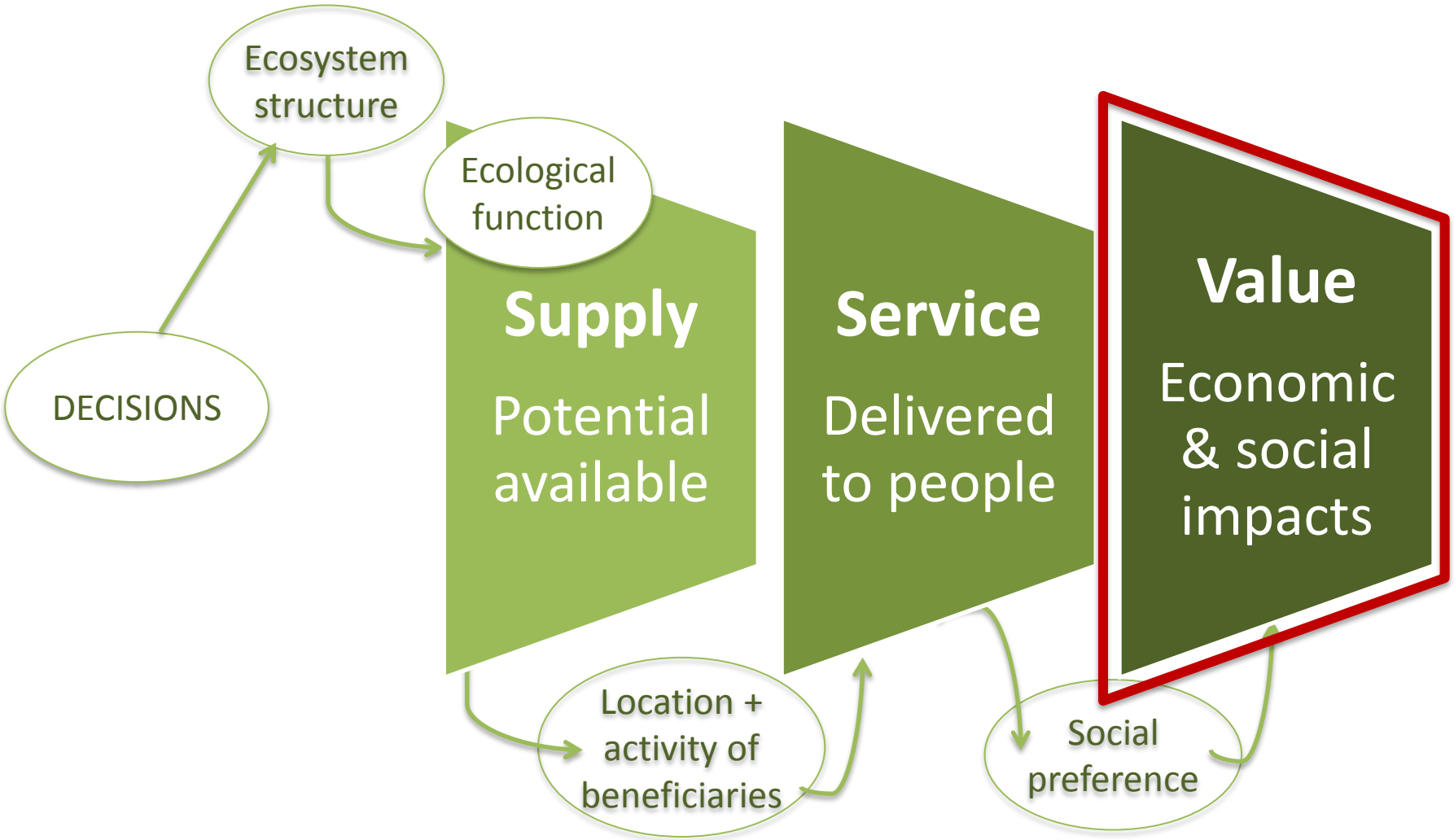


InVEST

integrated valuation of environmental services and tradeoffs

Questions?

The Natural Capital Approach



Value of ecosystem services

- Value of ecosystem services depends on "human welfare" derived from nature
  - safety
  - material needs
  - health
  - spiritual satisfaction
  - social relations

- Monetary unit is used as a common metric to compare aspects of welfare
  - Widely recognized, comparable to other services
  - Easily incorporated into decision-making

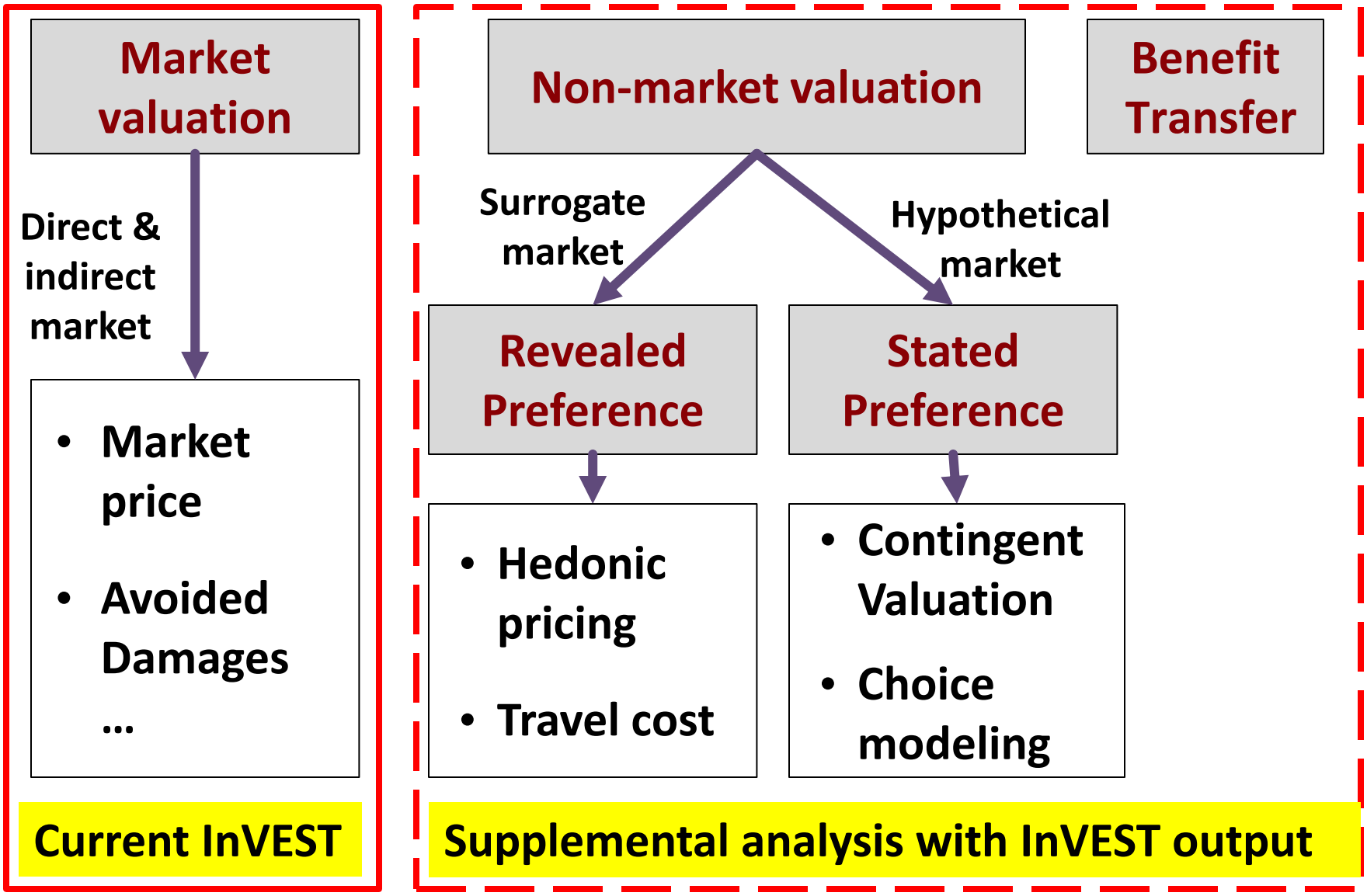
It's not all about money, it's human well-being

Why value ecosystem services?

- Value total flow of benefits from ecosystems
- Evaluate net benefits of interventions
- Determine distribution of costs and benefits
- Identify service providers and beneficiaries to ascertain potential funding for conservation

Pagiola, von Ritter & Bishop 2004

Valuation methods in InVEST



Market price method

- Actual prices of goods/services
  - InVEST examples:
    - Timber, fish, non-timber products, agricultural products
    - Hydropower, wave energy
    - Carbon Sequestration (permit price)

Avoided damages method

- Costs incurred in the absence of the service, measuring prices of equivalent non-ecosystem services
  - InVEST examples:
    - Water Purification: Nutrient Retention (water treatment)
    - Sediment Retention (dredging)
    - Carbon Sequestration (social cost)
    - Storm Peak Mitigation (dam)

Valuation methods in InVEST

Method	ES type	InVEST model
Market price	**Provisioning Service**	**Fish Aquaculture** **Managed Timber Production** **Wave Energy** **Reservoir Hydropower Production** **Agricultural Production** **Non-timber Forest Product Production**
	Regulating Service	**Carbon Sequestration** **Water for Irrigation**
Avoided cost	**Regulating Service**	**Nutrient Retention** **Sediment Retention** **Carbon Sequestration** **Storm Peak Mitigation**
Travel cost	**Cultural Service**	**Recreation**
Currently not valued	Cultural/Supporting /Regulating Services	Biodiversity/Habitat quality and rarity Marine habitat risk Coastal protection & vulnerability Aesthetic view

*models in grey are under development

Net Present Value (NPV)

- The Net Present Value (*NPV*) of an ecosystem service is the present value of the expected net benefit flows over time.

$$NPV = \sum_{i=0}^{T-1} \frac{Benefit_i - cost_i}{(1+r)^i}$$

Number of years present landscape conditions are expected to persist, or total years the service is valued for.

Discount rate (0%~100%): Weight of present benefits versus future benefits

Larger **r** →more weight on present

Pros and cons of economic valuation

- Pros
  - Built on economic theory
  - Yields estimates in common (monetary) metric
  - Powerful method to communicate value
- Cons
  - Some values are difficult to measure e.g. spiritual value
  - Valuation can be incomplete, biased and uncertain
- InVEST provides rapid and conservative estimates
  - Best used to compare tradeoffs of alternative scenarios
  - Validated value estimates better for absolute magnitude

InVEST
integrated valuation of environmental services and tradeoffs

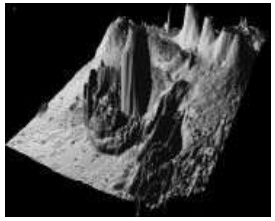
Sediment retention example

InVEST
integrated valuation of environmental services and tradeoffs

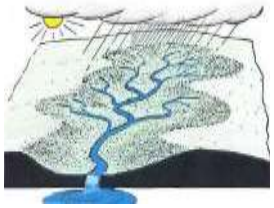
Sediment example: biophysical inputs

Land use/Land cover
+ associated factors affecting soil loss and retention

Streams

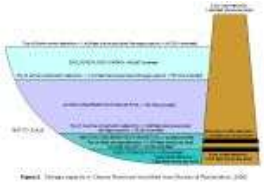


Slope



Watersheds

Rainfall erosivity



Sediment thresholds
(of reservoirs or water quality requirements)

Soil erodibility

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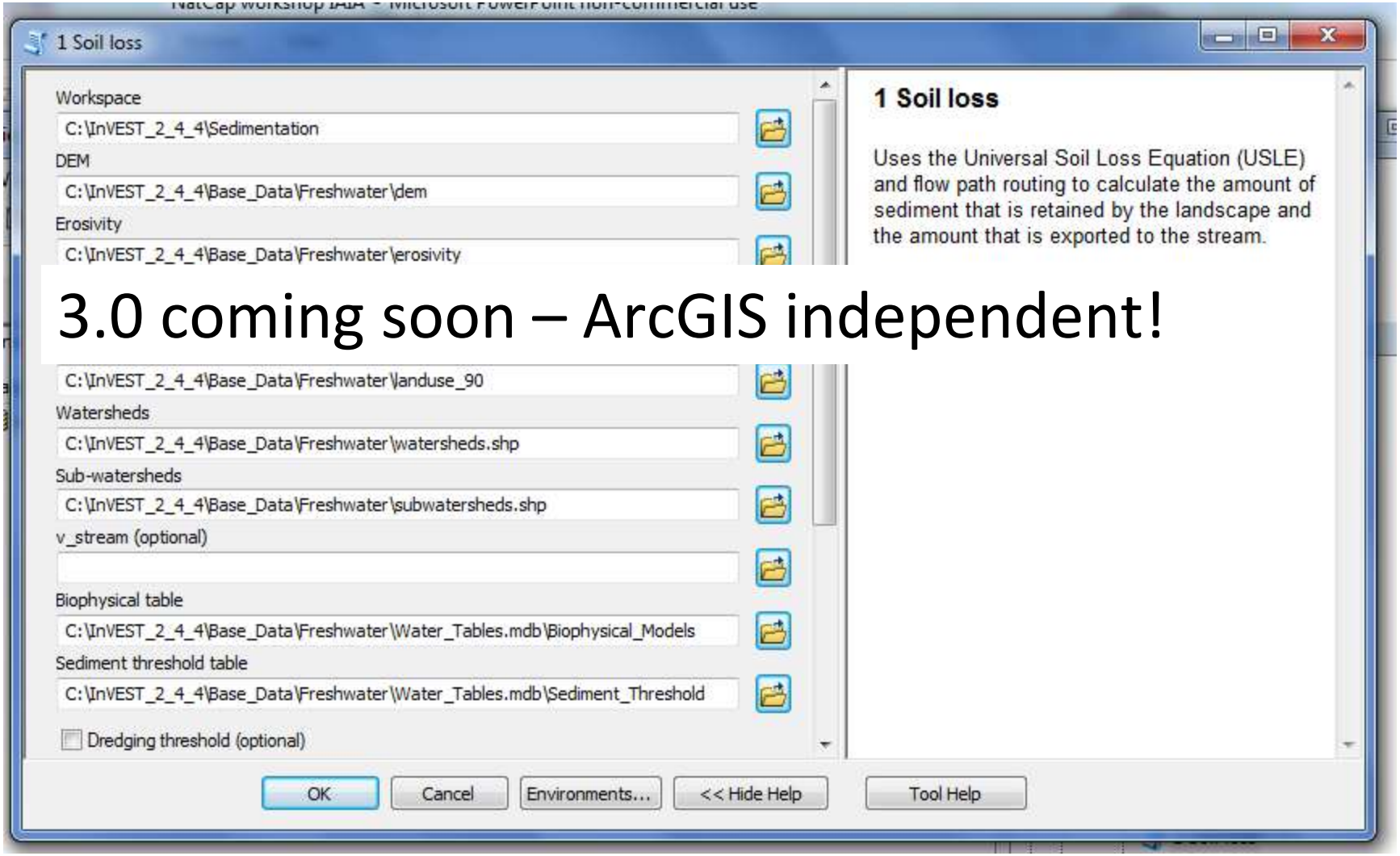
Sediment example: 2.x interface



3.0 coming soon – ArcGIS independent!

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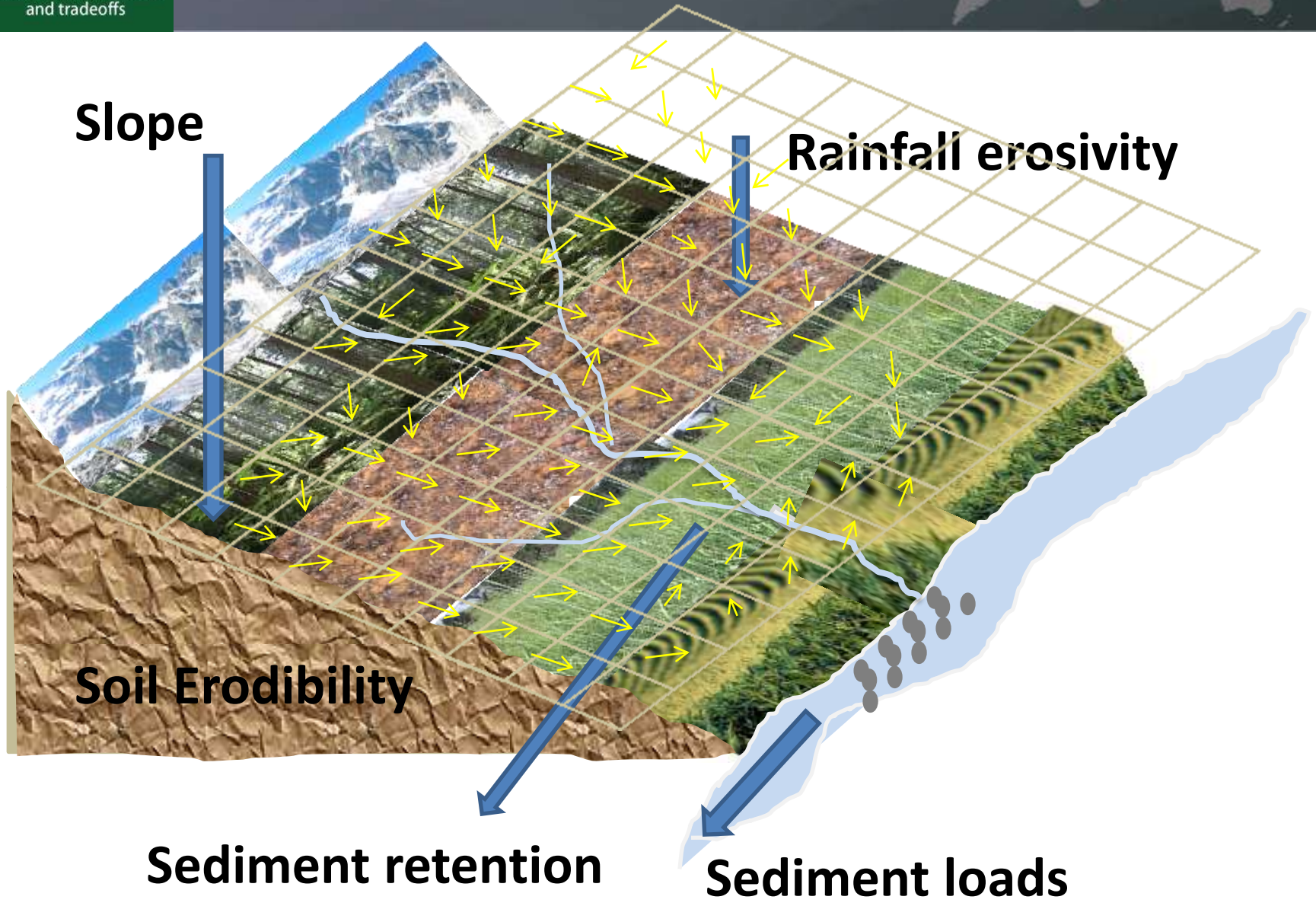
integrated valuation of environmental services and tradeoffs

Sediment retention model



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integrated valuation of environmental services and tradeoffs

Sediment retention model

Routed Universal Soil Loss Equation

Sediment held in place by vegetation

Upslope sediment trapped by vegetation

$$SED_{xD} = \left(R_x \cdot K_x \cdot LS_x \cdot \left(1 - C_x \cdot P_x\right)\right) + \left(SE_x \sum_{y=1}^{x-1} USLE_y \prod_{z=y+1}^{x-1} \left(1 - SE_z\right) \right)$$

R_x rainfall erosivity
K_x soil erodibility
LS_x slope length factor
C_x crop or vegetation factor
P_x support practice factor
SE_x sediment retention
$USLE_y$ RKSLCP of upslope pixels
SE_z sediment retention efficiency of downslope pixels

InVEST
integrated valuation of environmental services and tradeoffs

Sediment example: supply & service

Supply

Potential available

Sediment retained

Service

Delivered to people

Avoided sedimentation

(beyond sediment thresholds)

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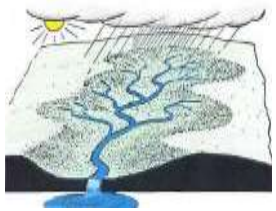
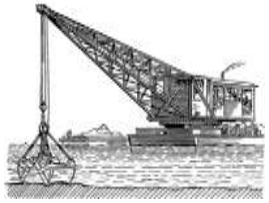
integrated valuation of environmental services and tradeoffs

Sediment example: valuation inputs



Watershed Areas

Sediment retained
From biophysical analysis



Sediment costs
Reservoir dredging costs or water treatment costs

InVEST
integrated valuation of environmental services and tradeoffs

Sediment example: supply & service

Supply

Potential available

Sediment retained

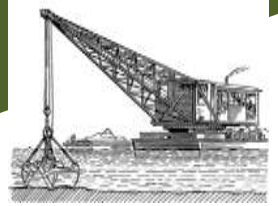
Service

Delivered to people

Avoided sedimentation

Value

Economic & social impacts



Avoided dredging or treatment costs

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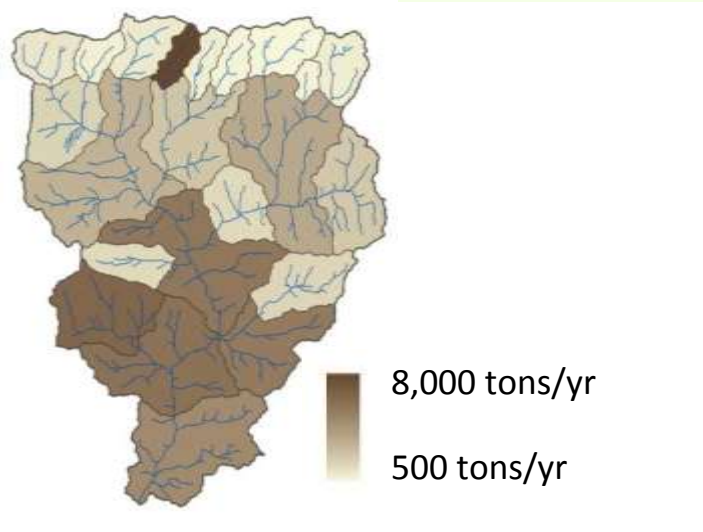
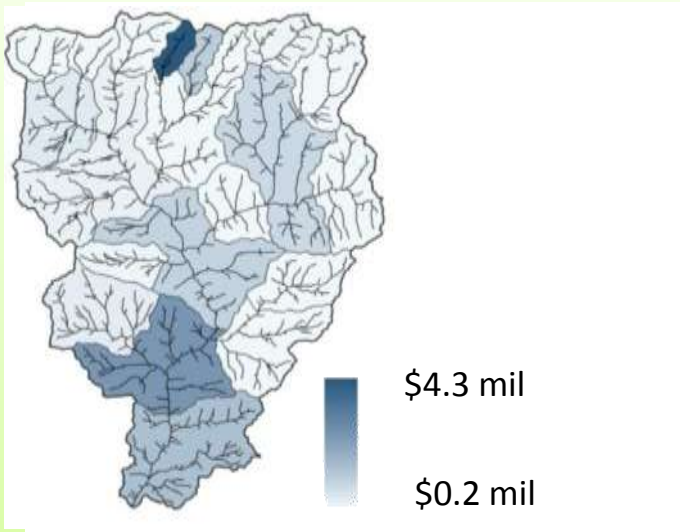
integrated valuation of environmental services and tradeoffs

Sediment example: outputs

AVOIDED SEDIMENTATION PER SUBWATERSHED

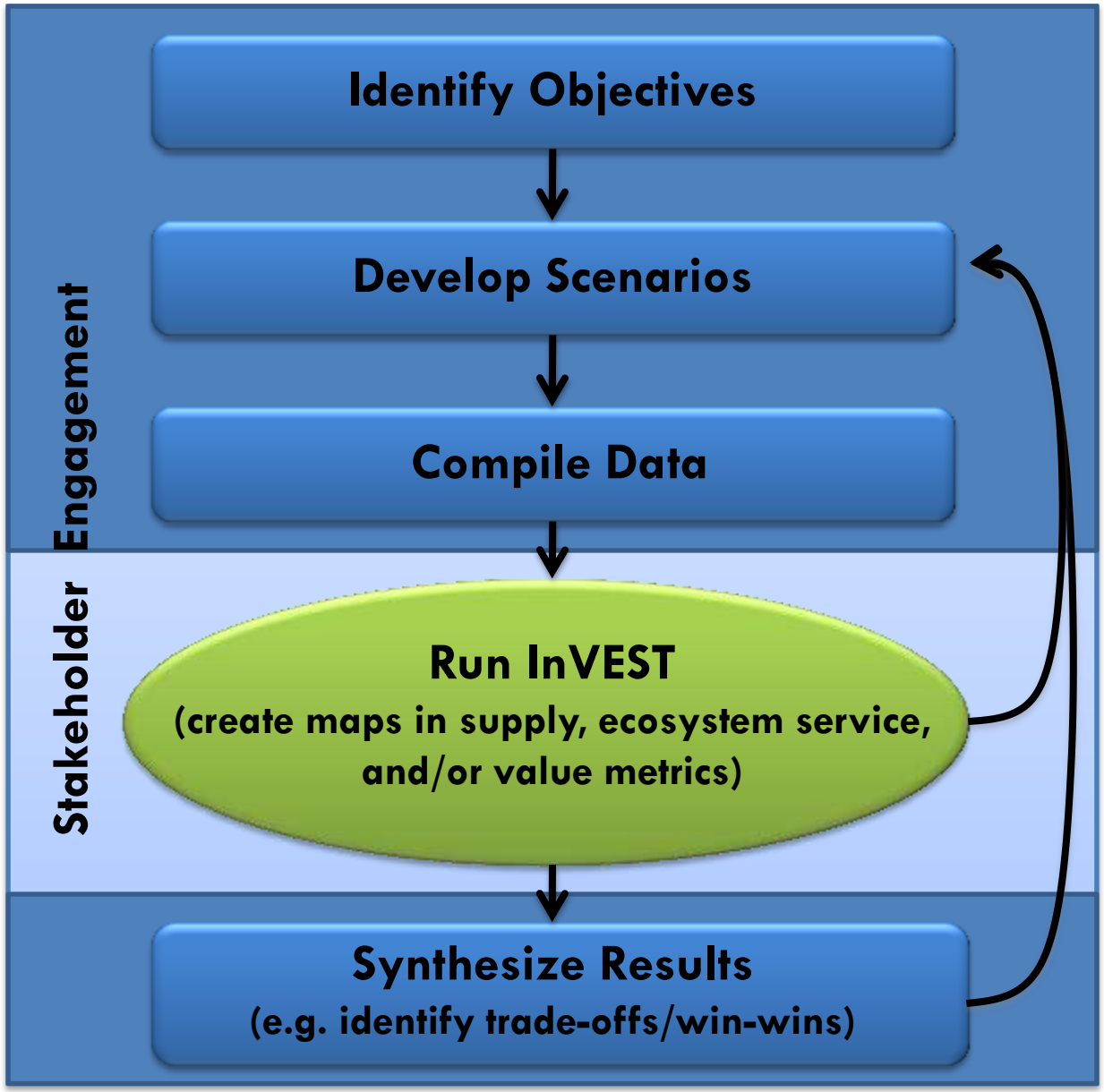


AVOIDED TREATMENT COST PER SUBWATERSHED



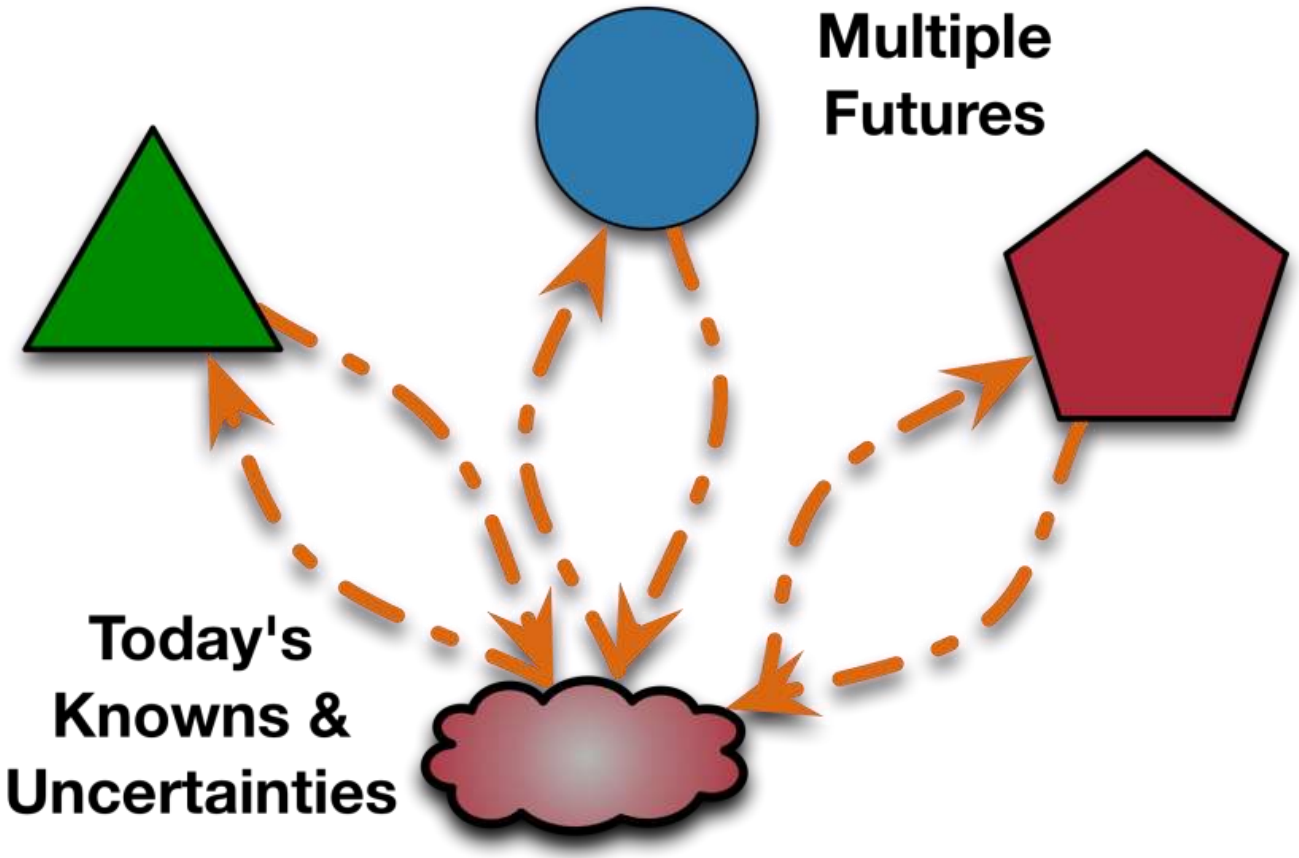
- Where are the sediment sources?
- Where is sediment retained?
- How much is retained?

- What is the value of this retention?
- How does this differ between scenarios?



What are scenarios?

- Plausible, simplified, descriptions of future

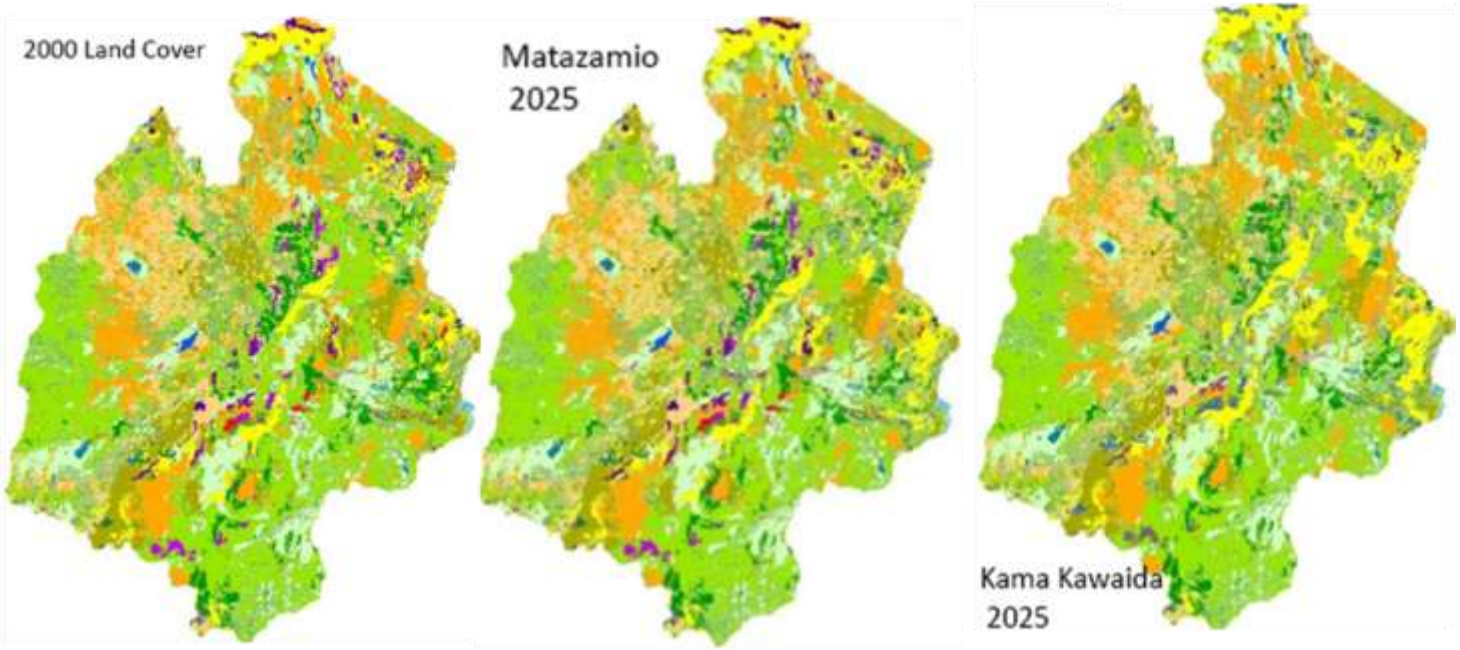


Types of scenarios

- Interventions
  - Designs for new policies, plans and projects
- Explorations
  - Possible but unexpected futures

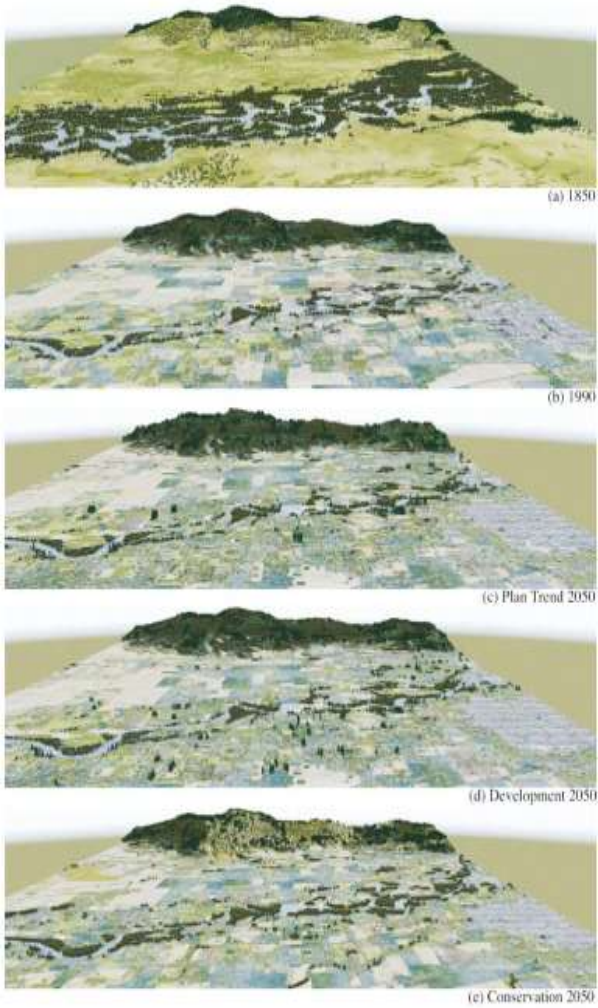
- Visions
  - Perceptions of desirable or undesirable futures
- Projections
  - Depictions of the expected future

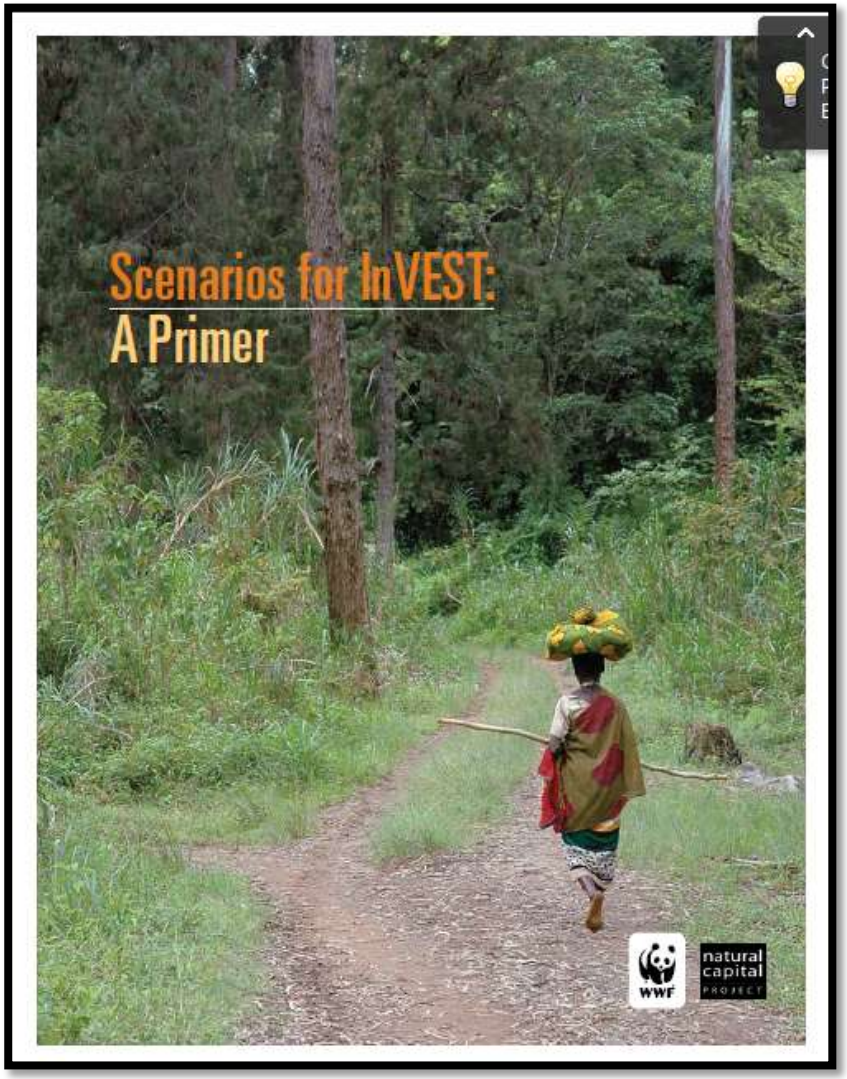
InVEST requires scenarios as maps of land cover and/or coastal and marine habitats and uses



Why use scenarios? (In practice)

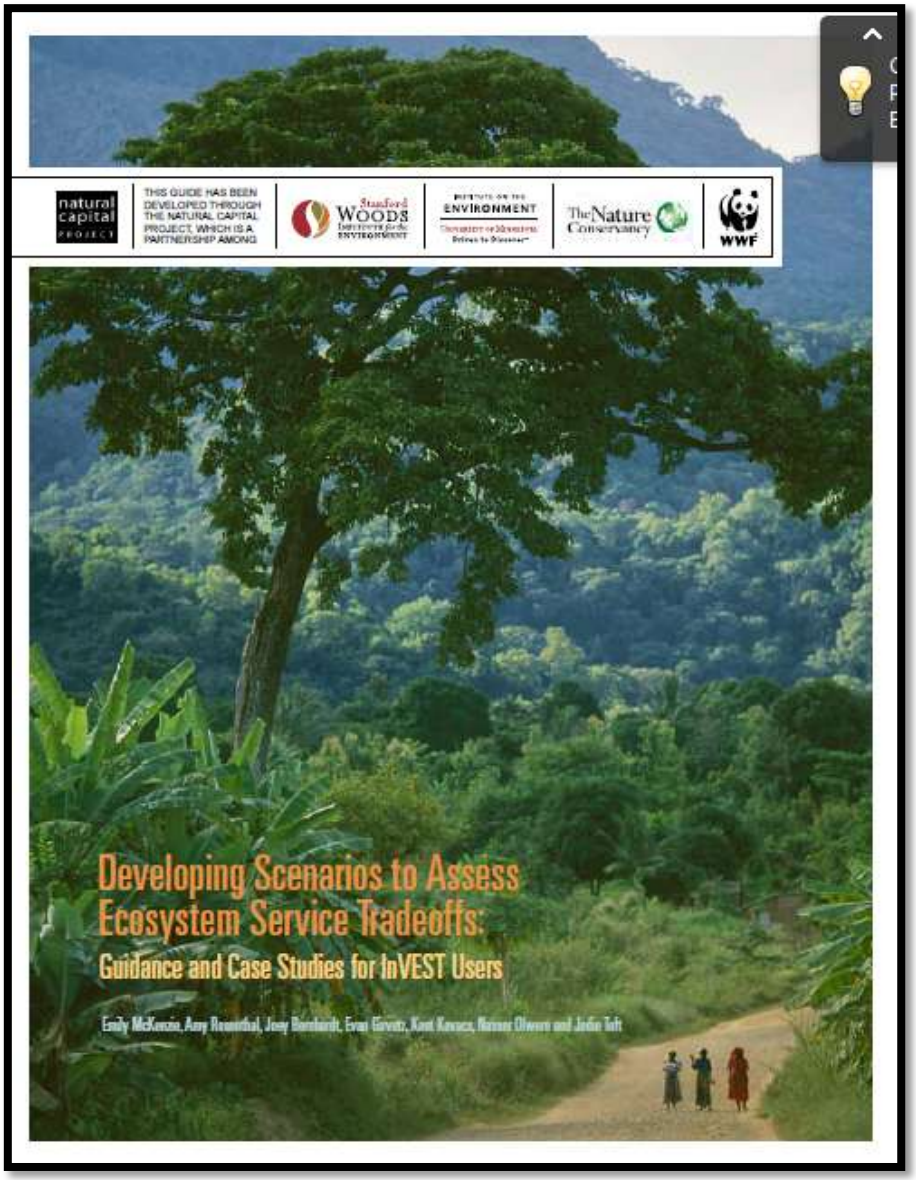
- Consider new policies/projects
- Identify tradeoffs
- ‘Future-proof’ policies
- Air conflicts, develop consensus
- Storytelling
- Process for iteration and learning

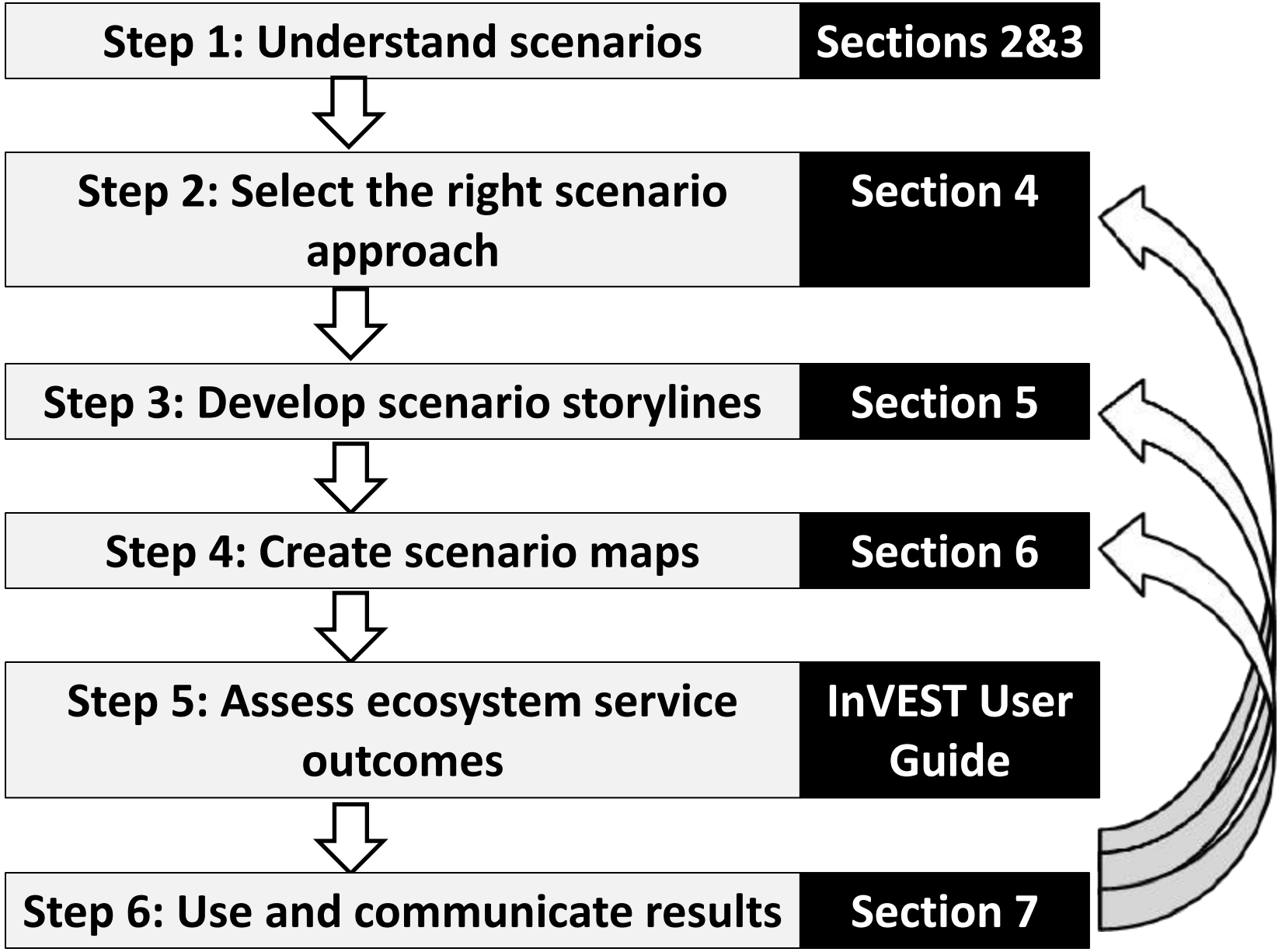




Primer

Guide and Case Studies





2. Select the right scenario approach

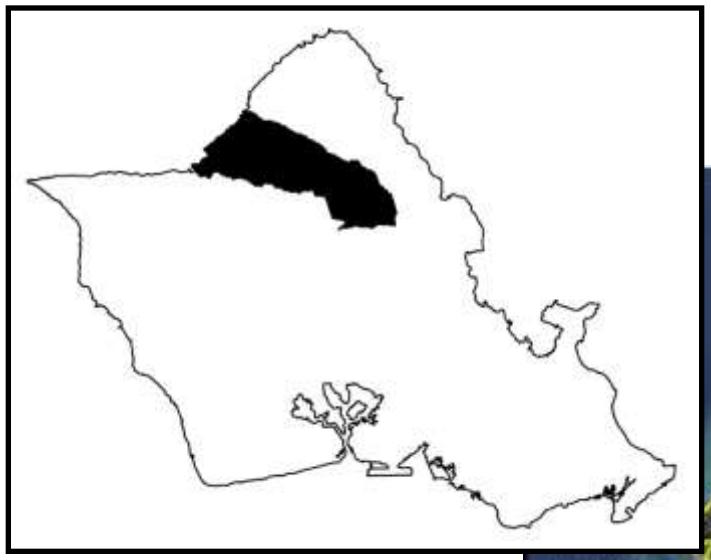
- Objective of InVEST analysis is the most important consideration

- It is useful to consider:
  - How can we engage stakeholders?
  - What (if any) quantitative scenario modeling is necessary?
  - How many scenarios do we need to develop?
  - At what scale?

Common approaches

- Desk study of policy, project and planning documents
- Literature review of similar interventions or drivers of change in similar contexts
- Workshops and/or interviews with decision makers and stakeholders
- Statistical or simulation modeling

Kamehameha School's Land Use Planning on North Shore, O`ahu



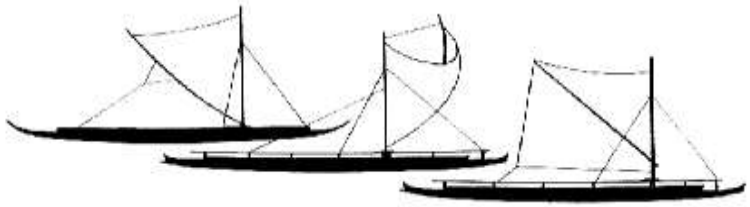
Island of O`ahu

Objective-- a balance of:

Economic value

Environmental value

Cultural value



Educational value

Community value

Approach

- A series of participatory discussions with Kamehameha Schools representatives and North Shore community
- Real opportunities + desire for future

3. Develop scenario storylines

- Both qualitative and quantitative methods exist

  A combined approach often works best.

- It easiest to start with a simple approach and then build upon that with more sophisticated methods if the time and technical capacity are available.

- Drivers are the foundation of scenarios

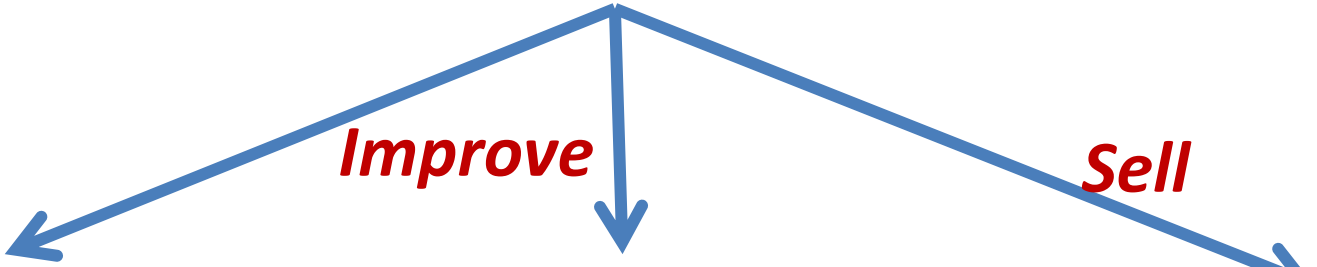
  They shape the direction, magnitude and rate of future change.

Drivers of change

Category	Drivers	
Social and demographic	•Population growth or decline •Migration •Cultural values •Awareness	•Poverty •Diet patterns •Education •Religious values
Technological	•Technological innovation	•Technology choice
Economic	•Economic growth •Trade patterns and barriers •Commodity prices	•Income and income distribution •Market development •Demand and consumption patterns
Environmental	•Climate change •Air and water pollution	•Introduction of invasive alien species
Political	•Macroeconomic policy •Other policy, e.g. subsidies, incentives, taxes	•Governance and corruption •Property rights and land tenure •Land-use plans, zoning and management

Storylines for Hawaii case

- Use of largely abandoned agricultural lands



Biofuel (sugarcane) production

Diversified agriculture & forestry

Residential development

4. Creating scenario maps

- Work with stakeholders to **draw a map** for each scenario using paper maps or digital or online mapping tools.

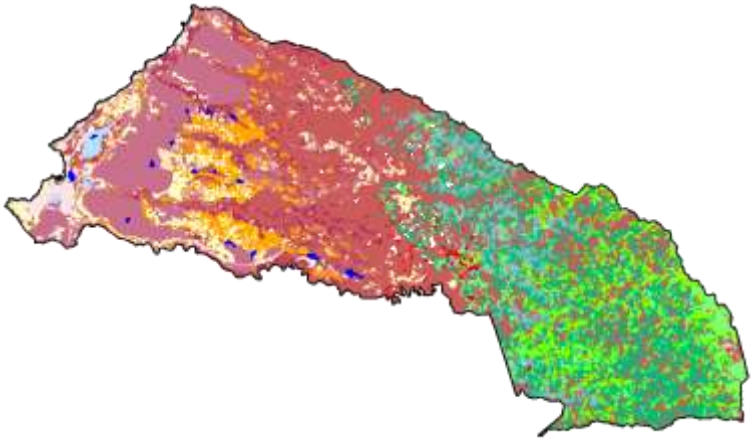
- Use **rules based on social, economic or biophysical principles** that define which areas are likely to be most suitable for particular uses or activities.

- Use past experience to **predict** where change is most likely to occur on the landscape or seascape, using **statistical methods**.

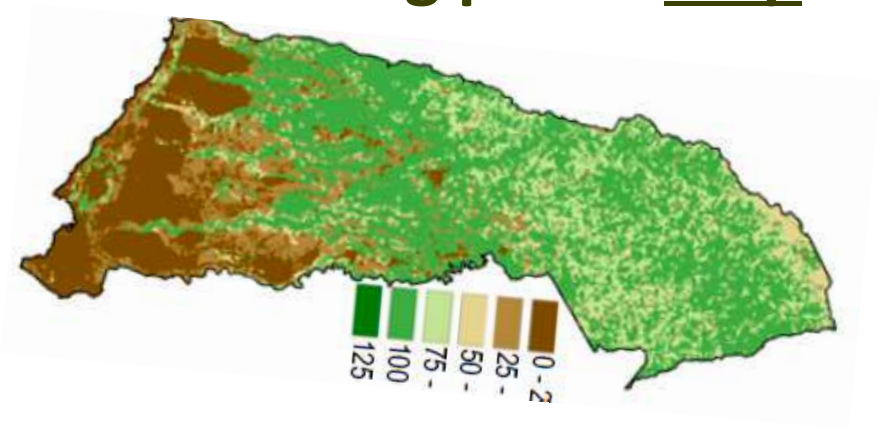
Qualitative rules	Quantitative rules
Agriculture can expand where the climate is suitable	800mm ≥ Annual Rainfall ≤ 1800mm
Agriculture will expand where the land is already near a road and near existing areas of agriculture	Distance to road ≤ 20km AND Distance to existing agriculture ≤ 20km
Agriculture will expand mainly in the wetland and coastal habitats. It will not expand into existing plantation forest.	Land-cover type ≠ urban, plantation forest or swamp
Agriculture will expand to suitable vacant land at historical rate until 2015 then slows	Existing vacant lands (soil class <3, slope<10) are randomly converted to agricultural lands at 5% rate for 2010-2015, at 2% after 2015

Scenario mapping for Hawaii case

2000 land use map

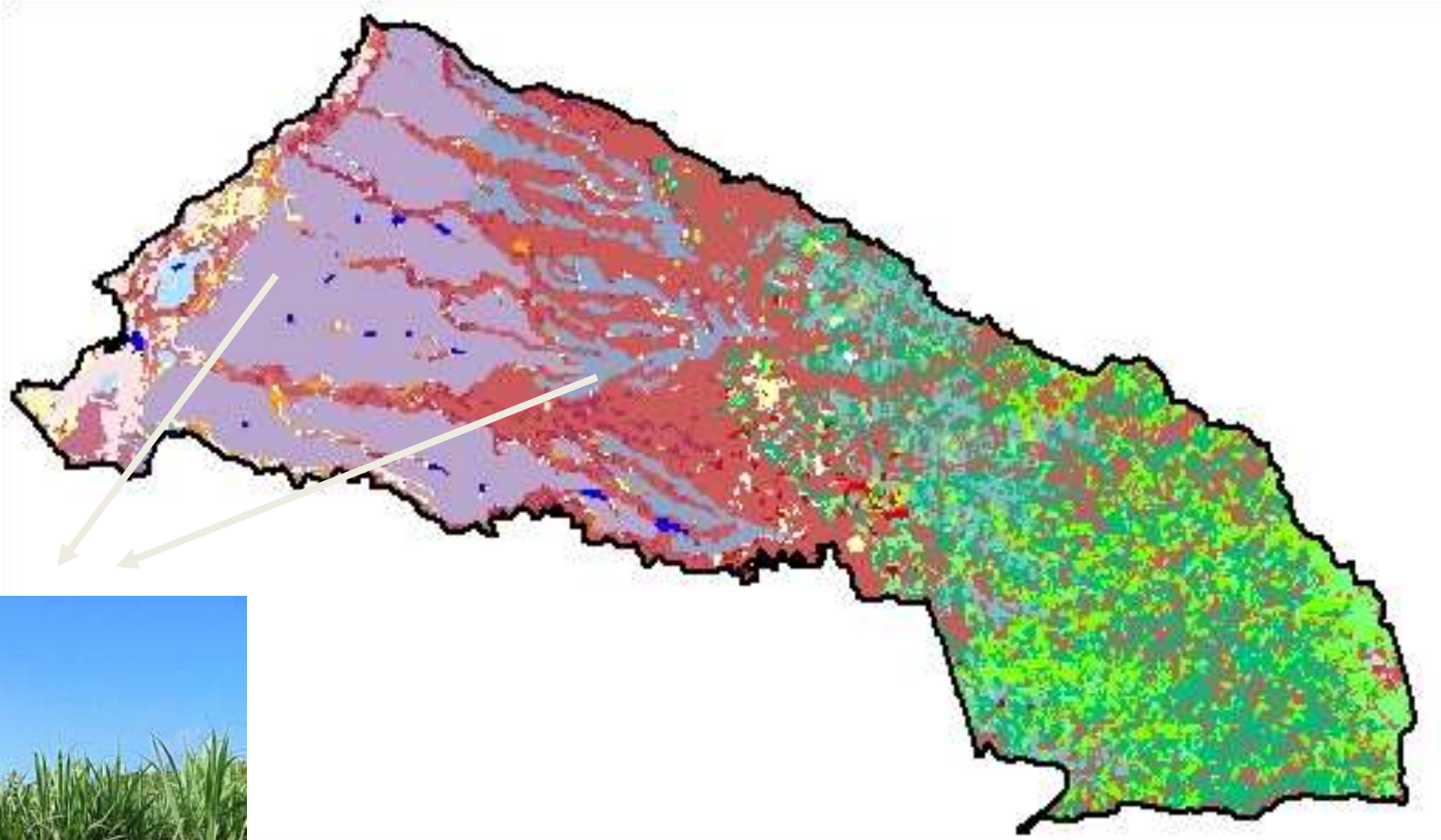


Coded Ag parcel map

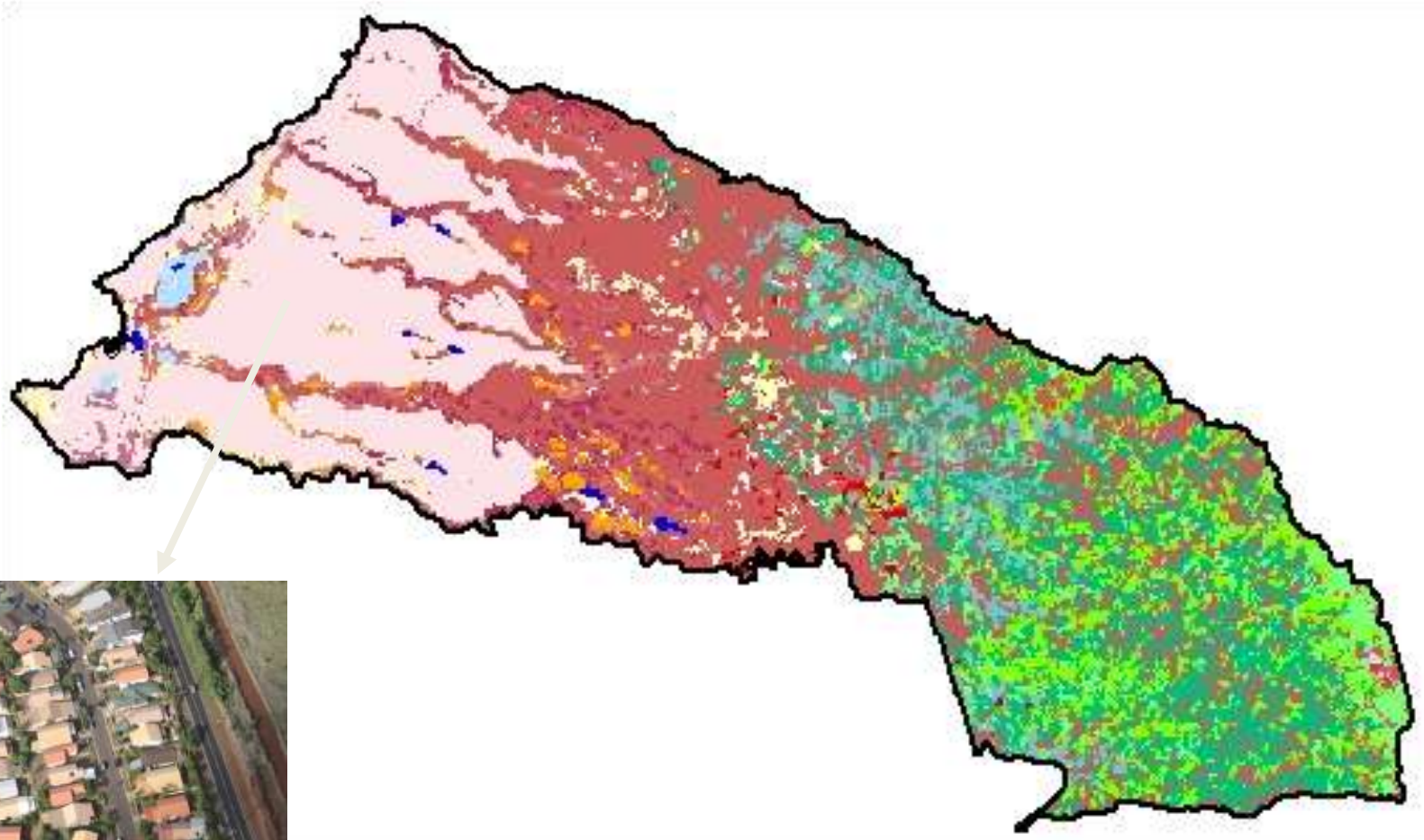


Discussion with landowner about rules

Growing a biofuels feedstock



Expanding residential development



Diversified agriculture & forestry

Reforestation

Food crop

5. Assess ecosystem service outcomes

Changes in Ecosystem Services (from current landscape)

Scenarios

Biofuels

Residential

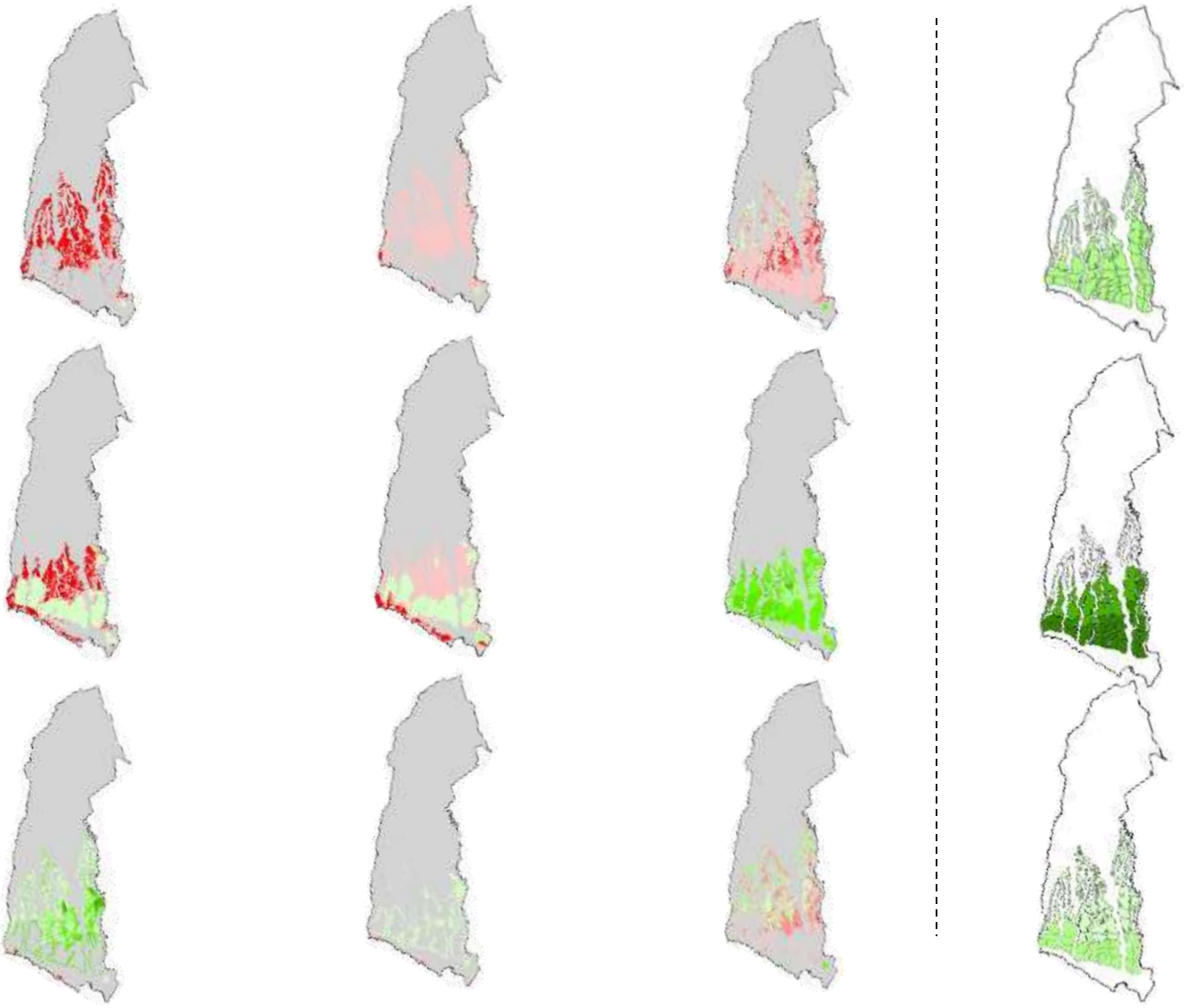
Sust. Agr. & Forestry

Carbon Storage (tC/ha)

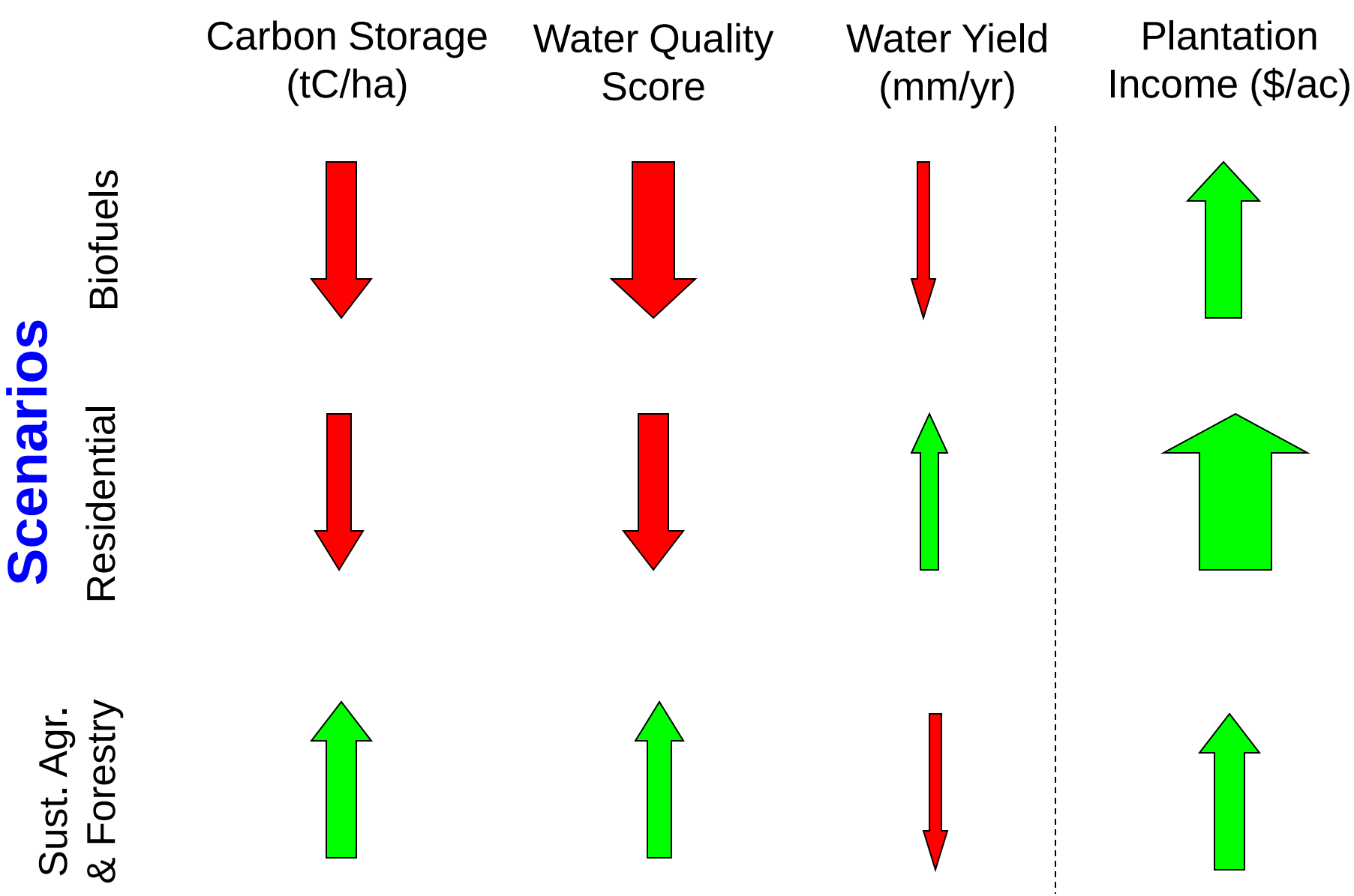
Water Quality Score

Water Yield (mm/yr)

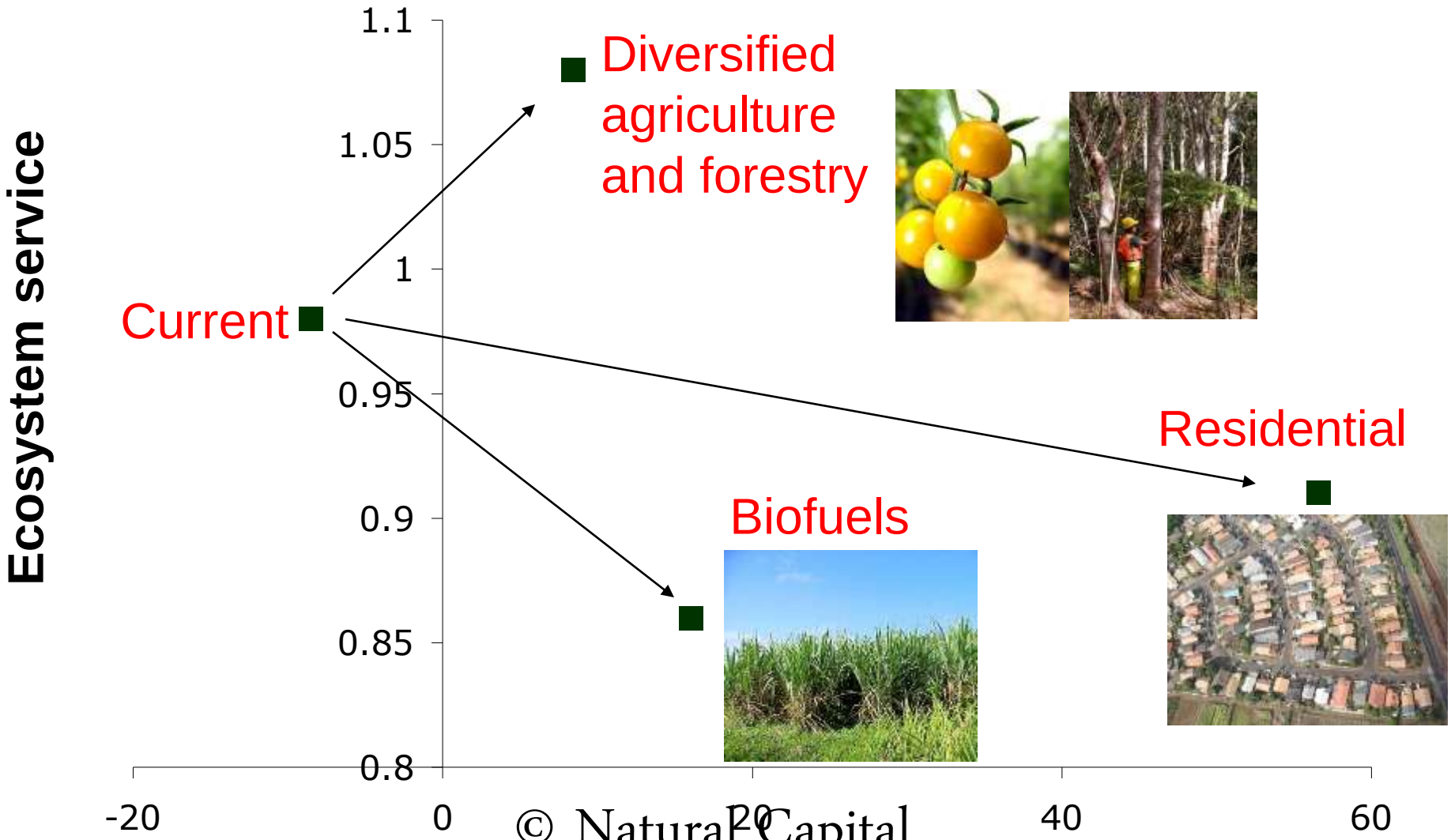
Income ($/ac)



Changes in Ecosystem Services (from current landscape)



Ecosystem Service vs. Market Value



6. Use and communicate results

Kamehameha School's Decision

Agriculture and forestry provide the most benefits all around.

6. Use and communicate results

PNAS

Integrating ecosystem-service tradeoffs into land-use decisions

Joshua H. Goldstein[a,1], Giorgio Caldarone[b], Thomas Kaeo Duarte[b], Driss Ennaanay[c,d], Neil Hannahs[b], Guillermo Mendoza[e], Stephen Polasky[f,g], Stacie Wolny[c,d], and Gretchen C. Daily[c,d,1]

[a]Department of Human Dimensions of Natural Resources, Colorado State University, Fort Collins, CO 80523; [b]Land Assets Division, Kamehameha Schools, Honolulu, HI 96813; [c]Department of Biology and [d]Woods Institute for the Environment, Stanford University, Stanford, CA 94305; [e]Institute for Water Resources, US Army Corps of Engineers, Alexandria, VA 22315; and Departments of [f]Applied Economics and [g]Ecology, Evolution, and Behavior, University of Minnesota, St. Paul, MN 55108

Contributed by Gretchen C. Daily, February 17, 2012 (sent for review September 15, 2011)

The Natural Capital Project, Kamehameha Schools, and InVEST: Integrating Ecosystem Services into Land-Use Planning in Hawai`i

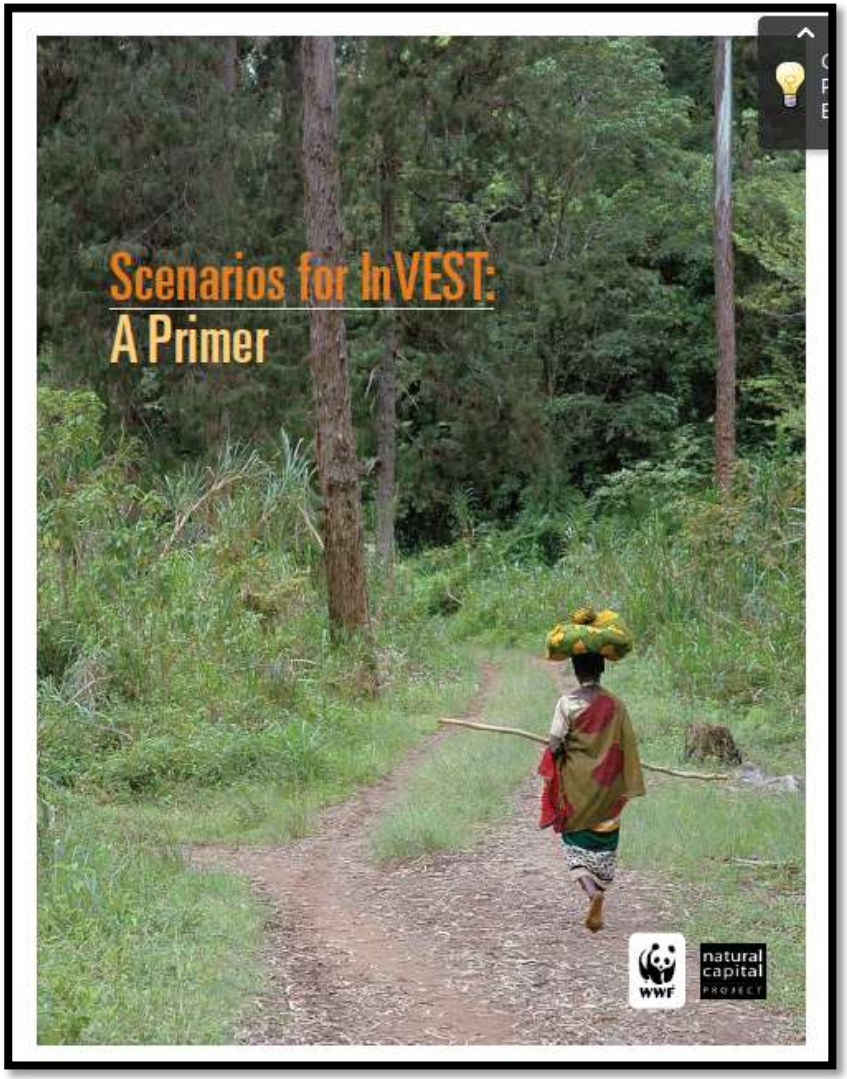
Authors: Joshua H. Goldstein, Giorgio Caldarone, Chris Colvin, T. Ka`eo Duarte, Driss Ennaanay, Kalani Fronda, Neil Hannahs, Emily McKenzie, Guillermo Mendoza, Kapu Smith, Stacie Wolny, Ulalia Woodside, and Gretchen C. Daily

Characteristics of effective scenarios

- Relevant
- Plausible
- Distinct
- Surprising
- Comprehensive
- Iterative
- Participatory

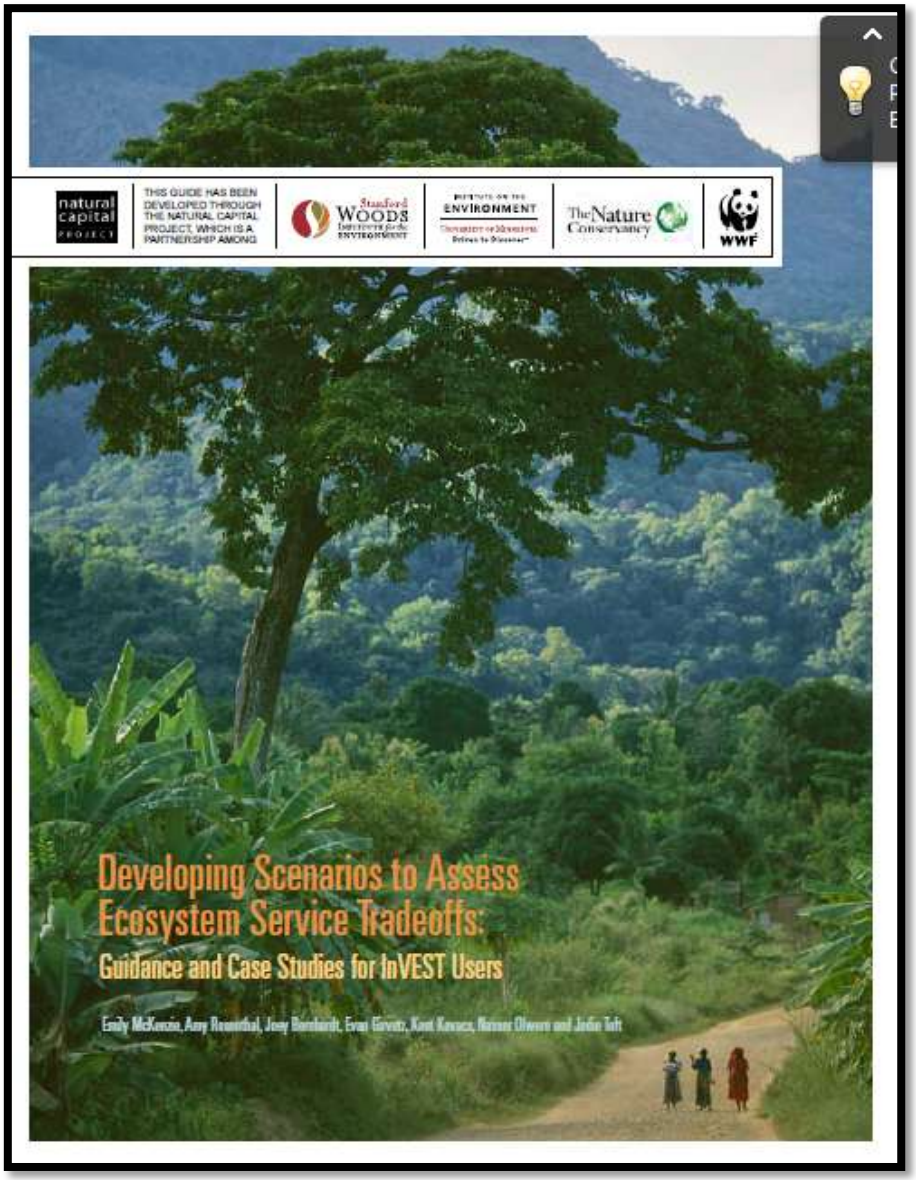
Scenario development is crucial and difficult….

We can help!



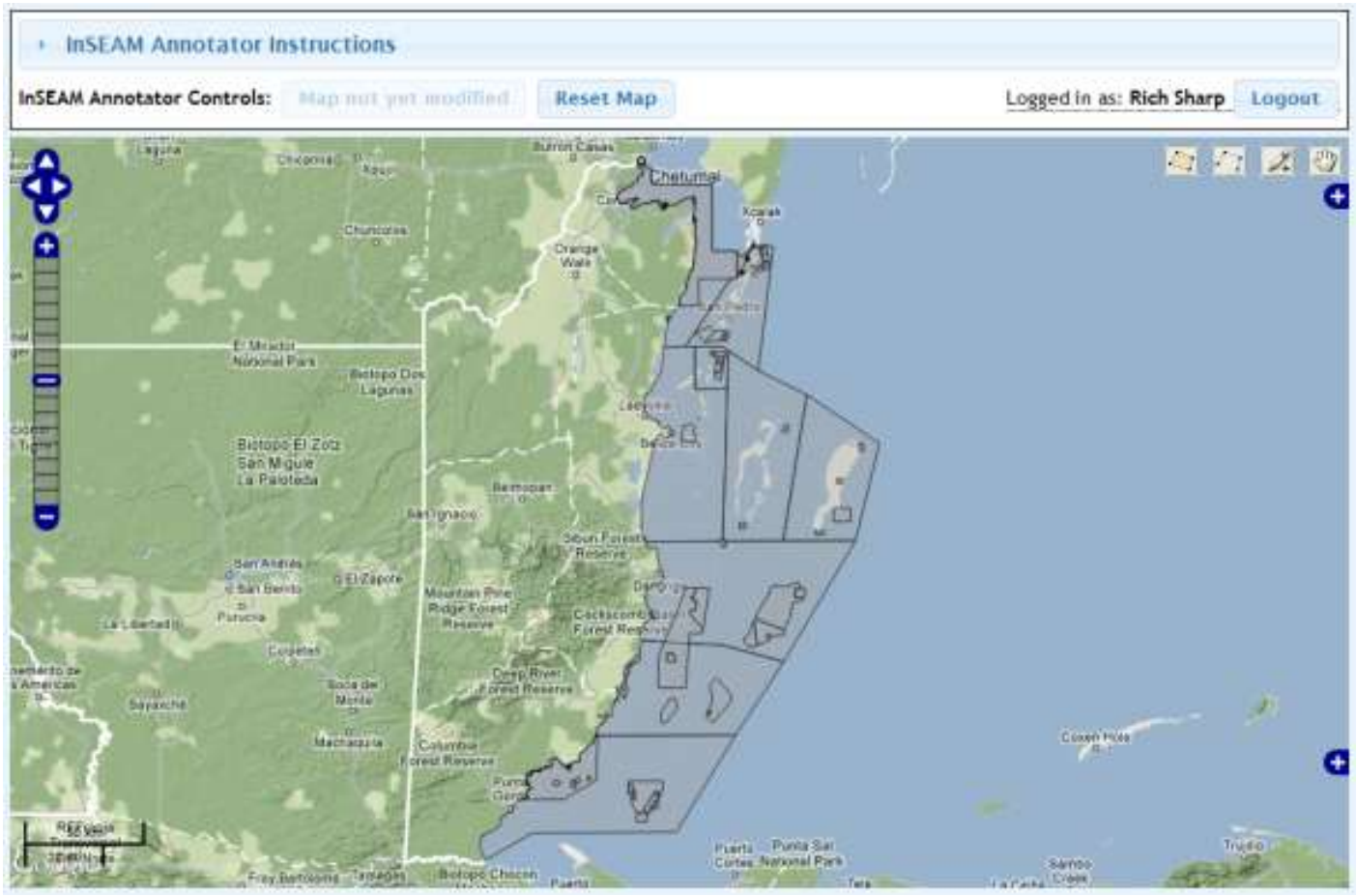
Primer

Guide and Case Studies



InSEAM (InVEST Scenario Modeler)

Online interactive community mapping tool



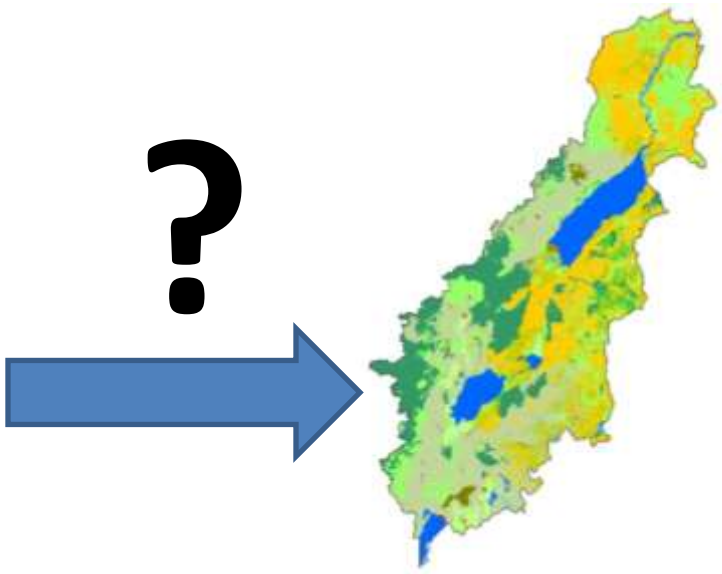
NatCap Scenario Generator

Simple, rule-based software

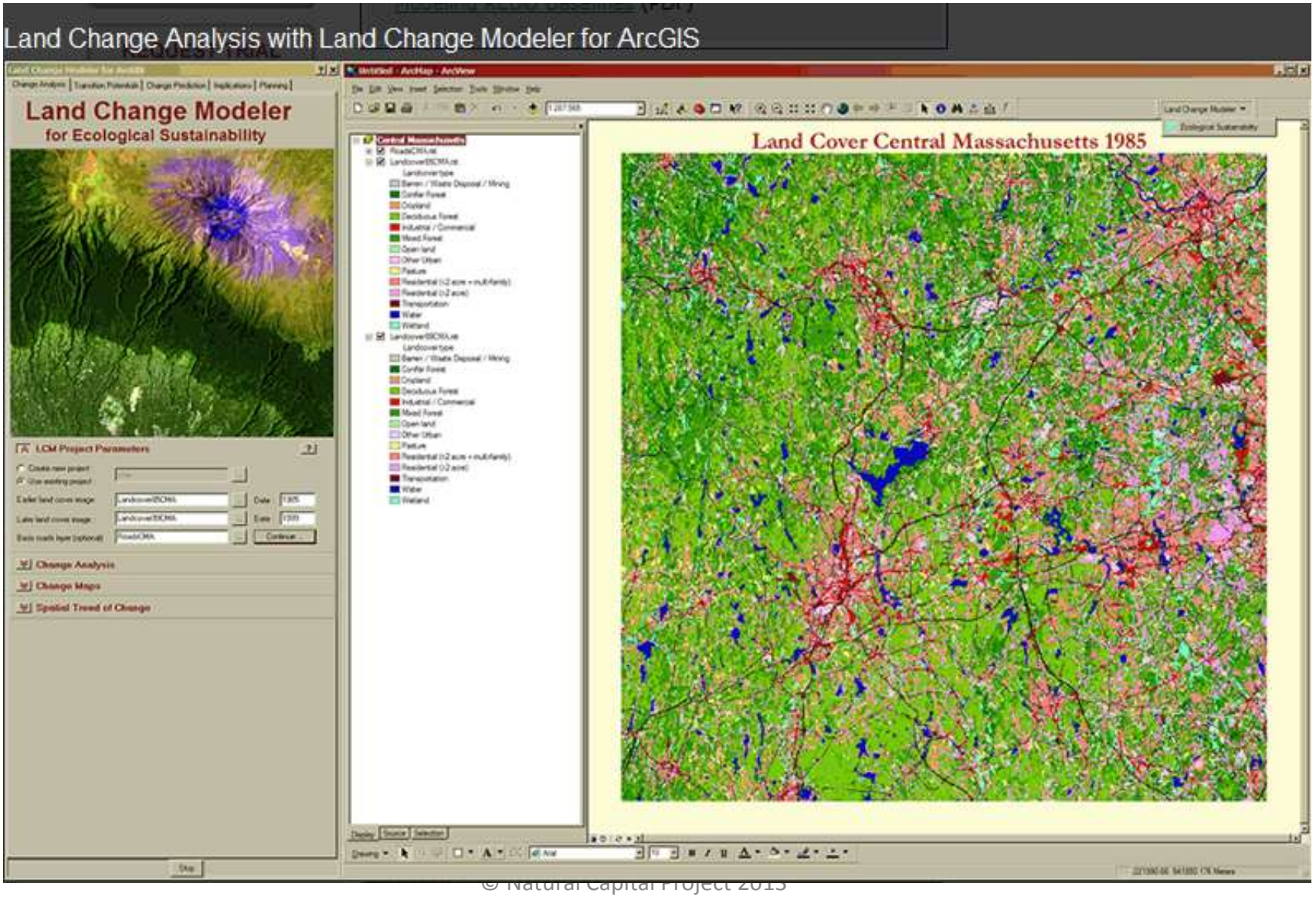
Add rules to translate storylines to maps

Only requires one land-cover map

Landcover Types	Change	Rules
Broadleaved tree plantation	increase	along roads, in poor soils, on hilltops, difficult to cultivate areas, in and around cfrs & lfrs,
Coniferous plantation	increase	along roads, in poor soils, on hilltops, difficult to cultivate areas, in and around cfrs & lfrs,
Tropical high forest	increase	in and around cfrs and lfrs, not in nps
Degraded forest	decrease	in and around cfrs and lfrs, not in nps
Woodland	increase	outside pas



InVEST link to IDRISI Land Change Modeler



More technical approaches

- General equilibrium simulation techniques
- Agent-based modelling
- Statistical techniques
- Markov-cellular automata models
- Optimisations

- Climate scenarios

Many scenario building models

- Metronamica
- PoleStar
- IMAGE
- WaterGAP
- AIM
- T21
- GLOBIOM
- Mirage
- CLUE
- GTAP/MAGNET
- LandSHIFT
- International Futures Model
- IDRISI Land Change Modeler
- Marxan
- Dinamica
- GEOMOD

InVEST

integrated valuation of environmental services and tradeoffs

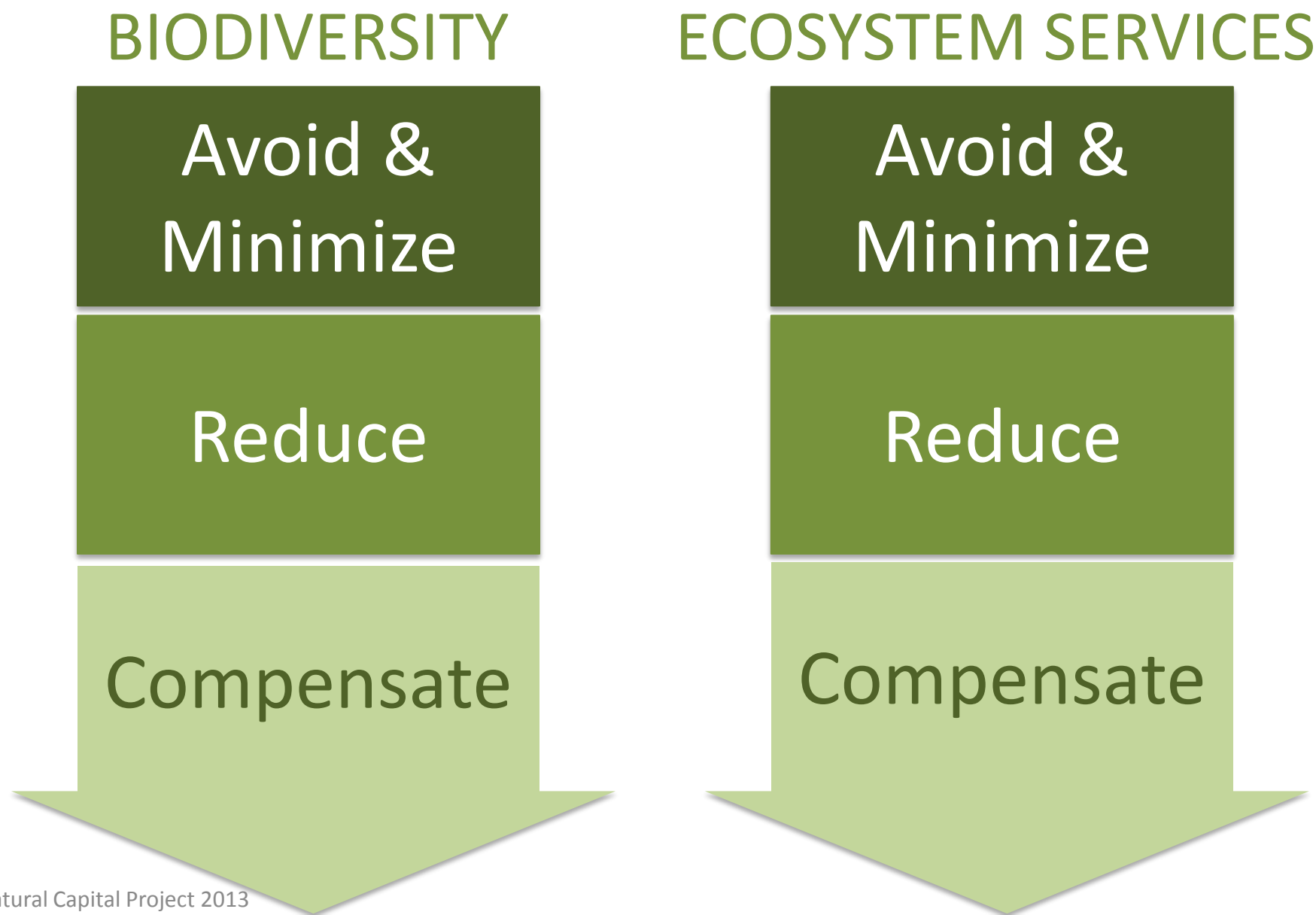
Questions?

Ecosystem services in development and mitigation:

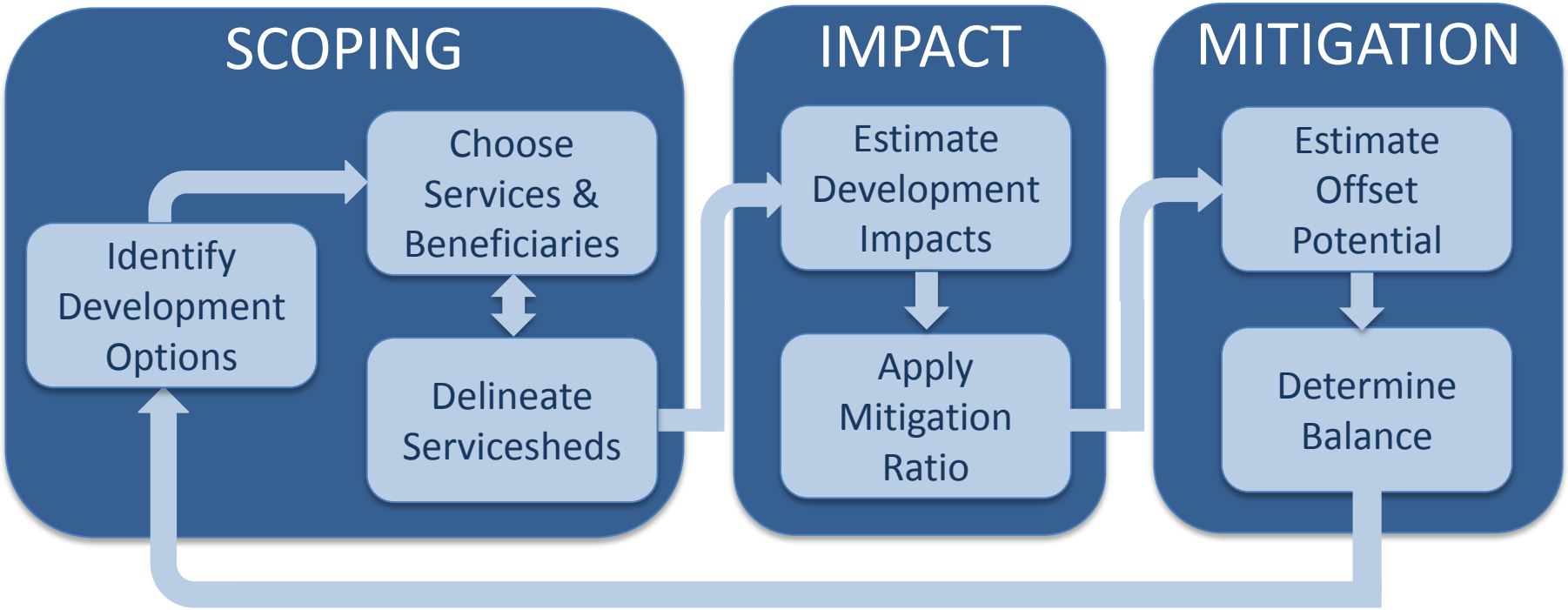
Can the Pucallpa-Cruzeiro do Sul Road be built with no net loss of ecosystem services?

NatCap & TNC
Lisa Mandle, Heather Tallis, Stacie Wolny, Adrian Vogl, Sofia Vargas, Jerry Touval, Leonardo Sotomayor, Dazolony Quintero, Paulo Petry, Marcelo Guevara, Luis Alberto Gonzales, Juan Carlos Gonzales and Luis Davalos

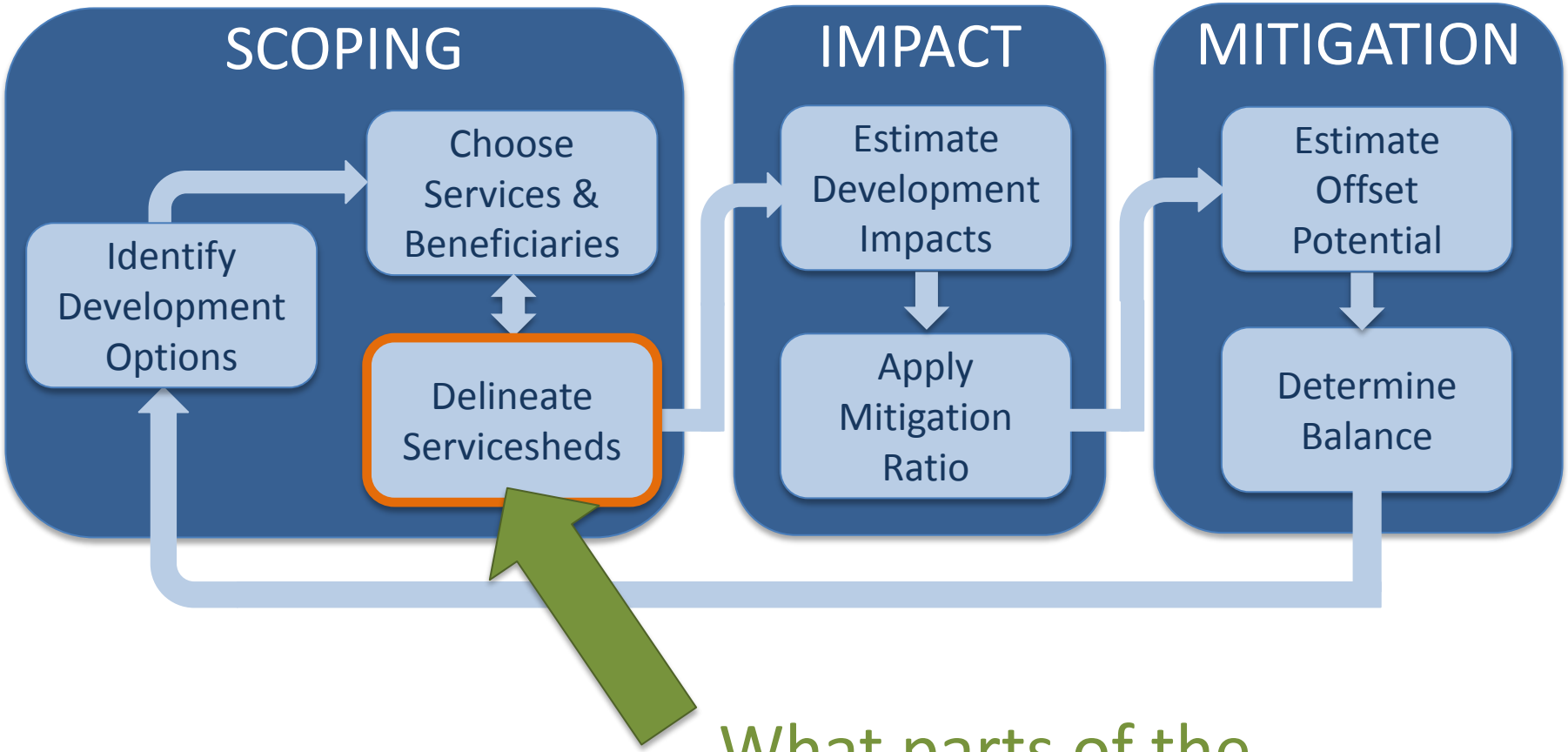
Developing a parallel approach



Ecosystem services in permitting & mitigation decisions

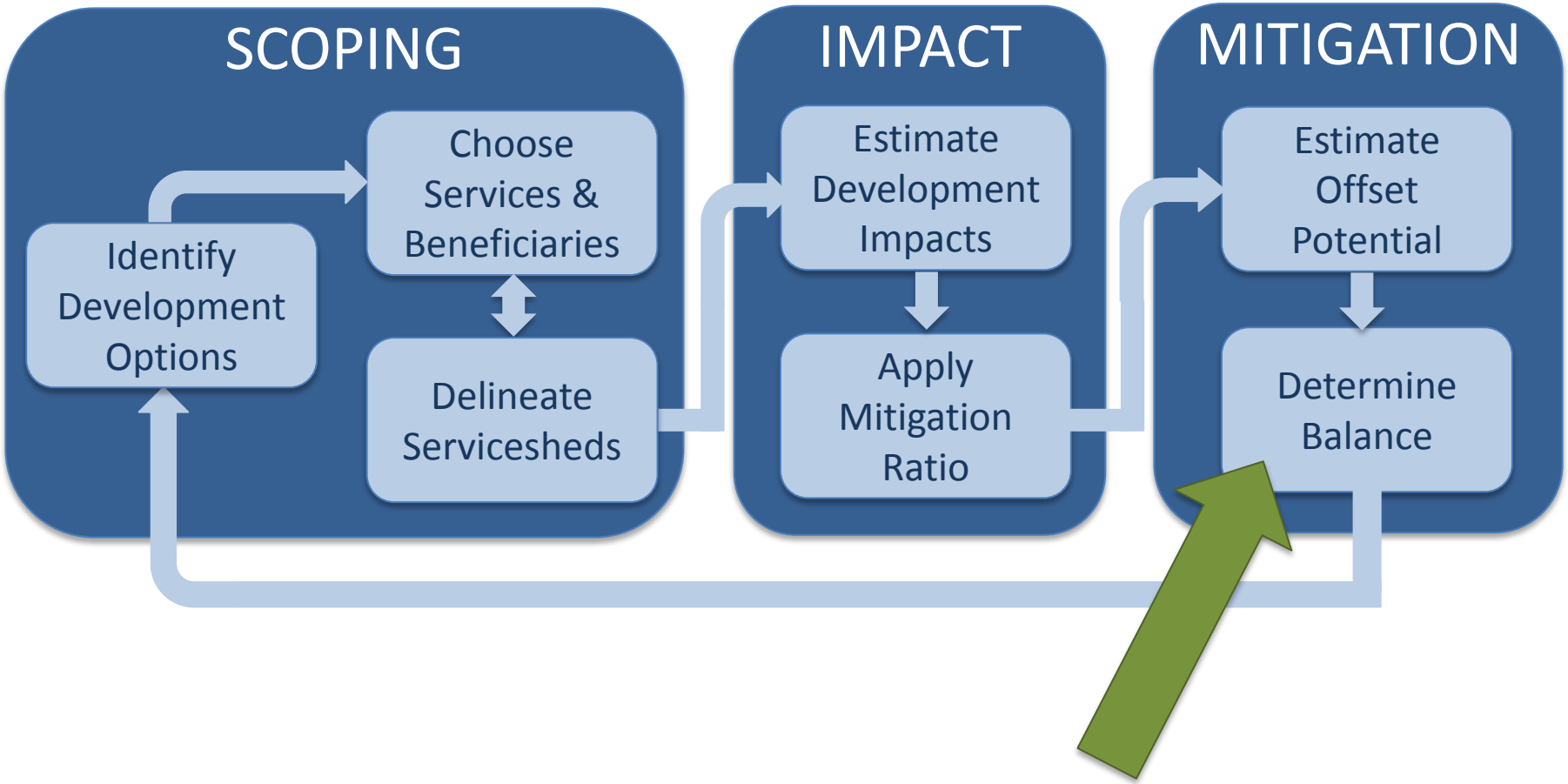


General Framework



What parts of the landscape provide services to which people

General Framework



Is no net loss possible?

Who is impacted?

By how much?

Servicesheds

Serviceshed: area with potential to provide a service to a specific beneficiary

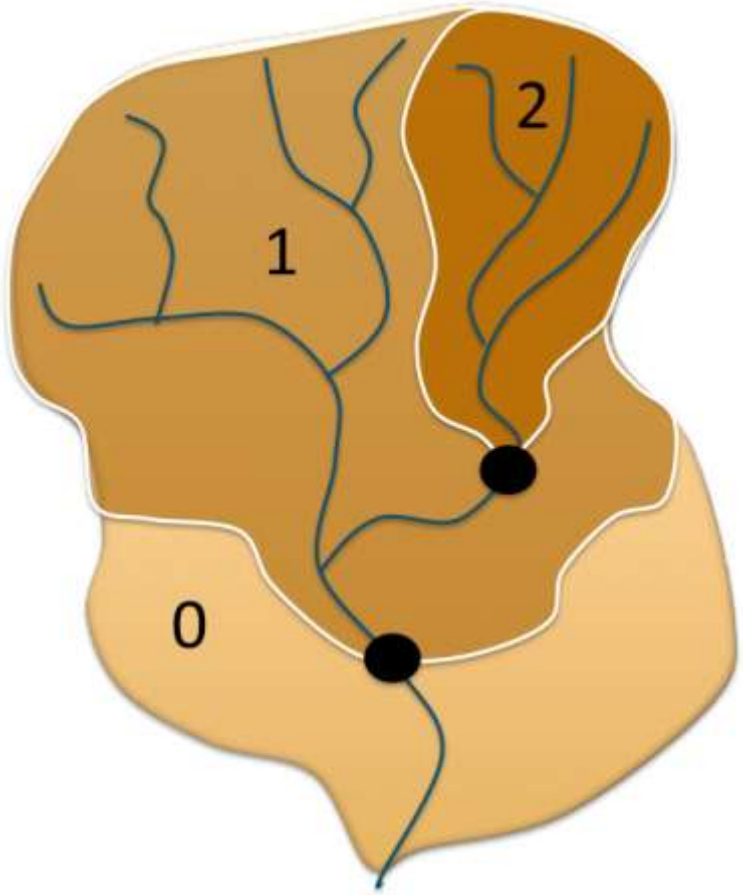
- Supply
- Physical access
- Institutional access



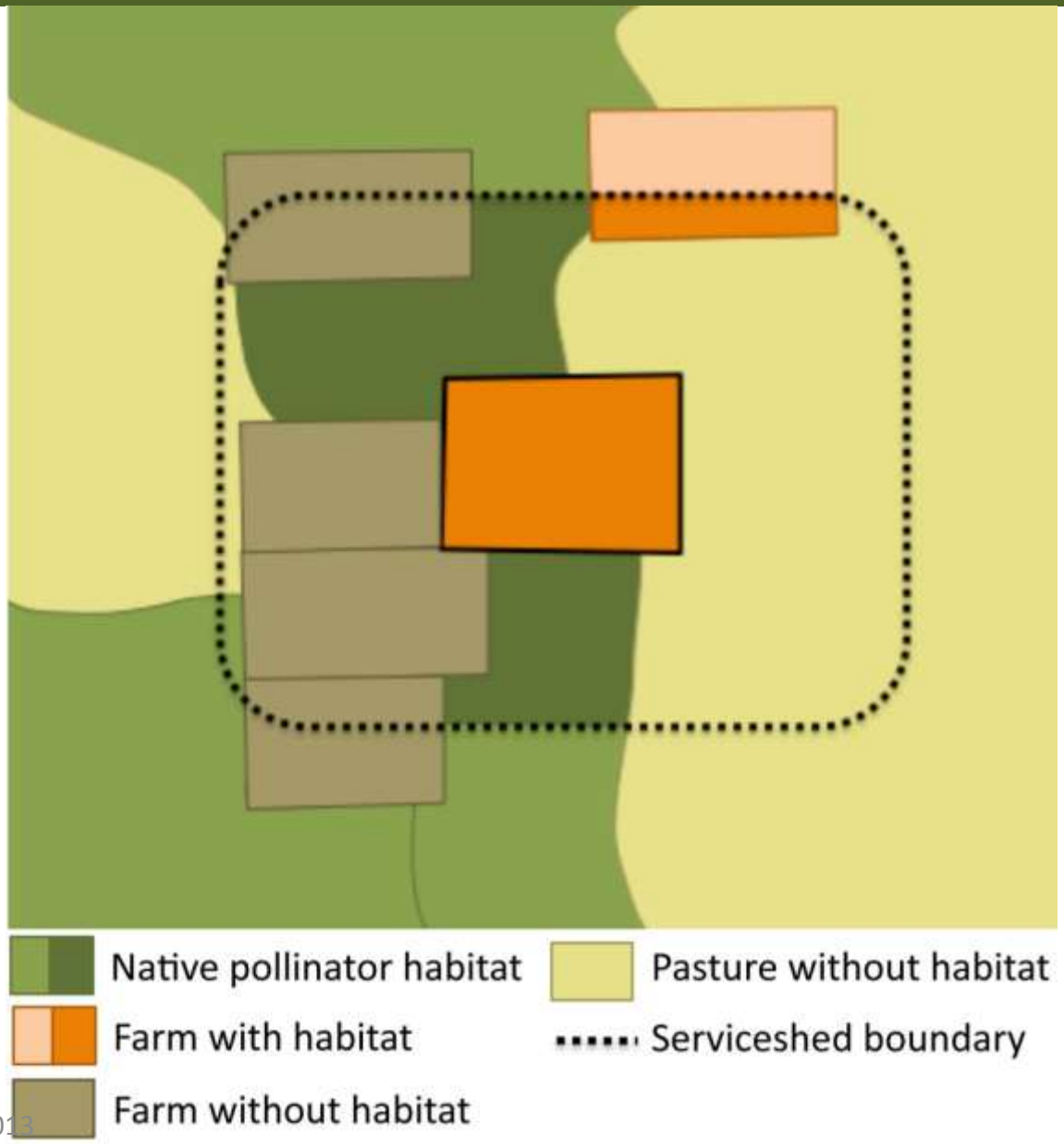
Servicesheds

Carbon

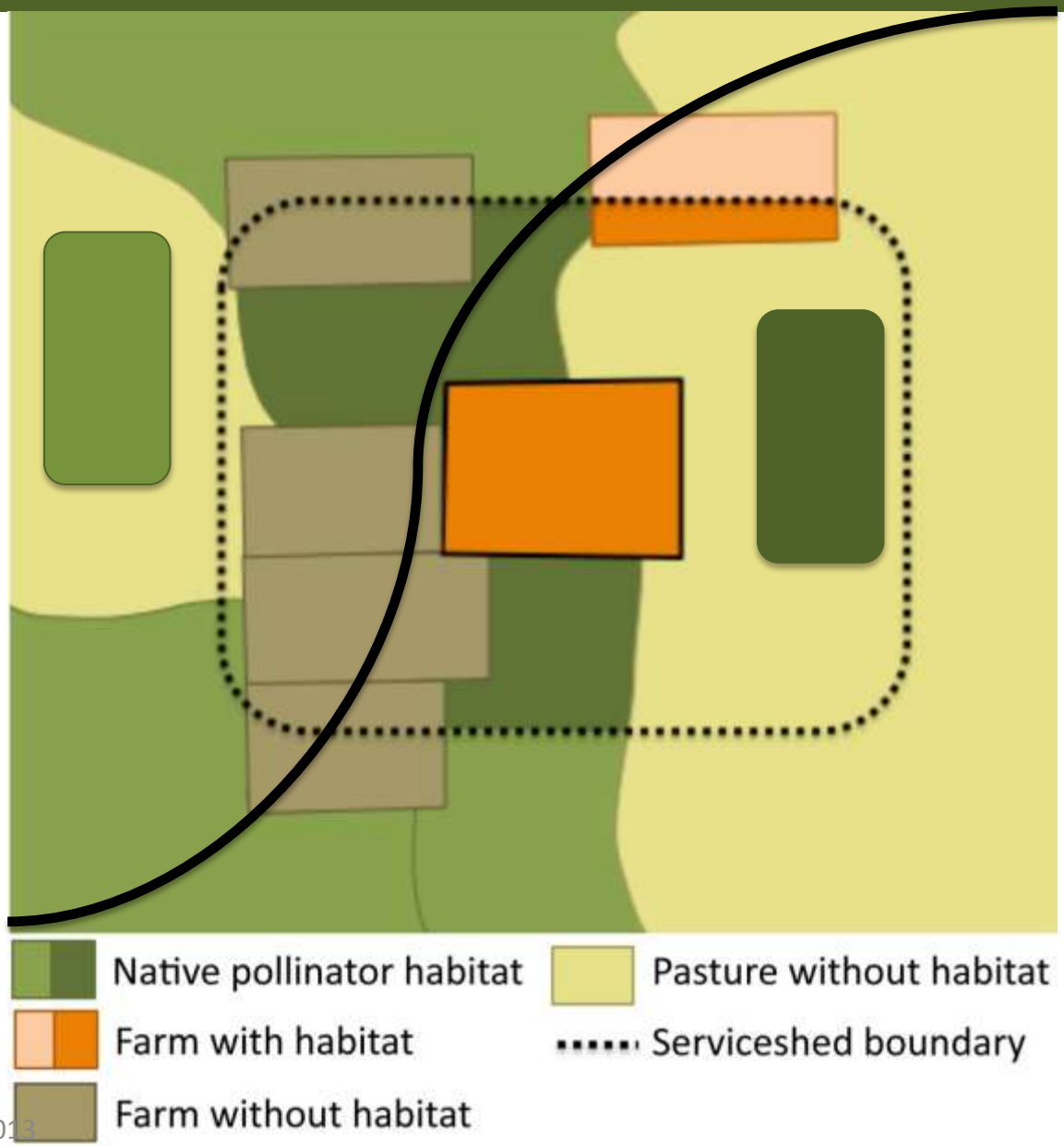
Water



Pollination



Pollination



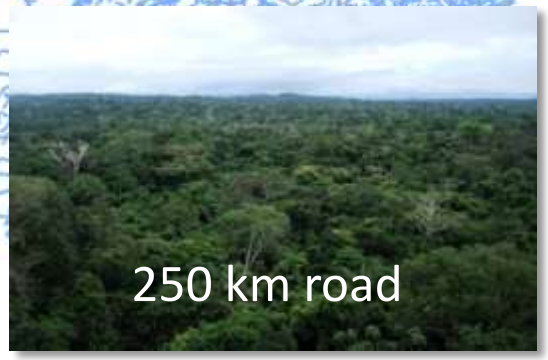
Proposed Road

SCOPING | IMPACT | MITIGATION

Peruvian Amazon

Pucallpa, Peru

Cruzeiro do Sul, Brazil



Beneficiaries

SCOPING | IMPACT | MITIGATION

Towns as beneficiaries
Local population >200,000

Services & servicesheds

SCOPING | IMPACT | MITIGATION

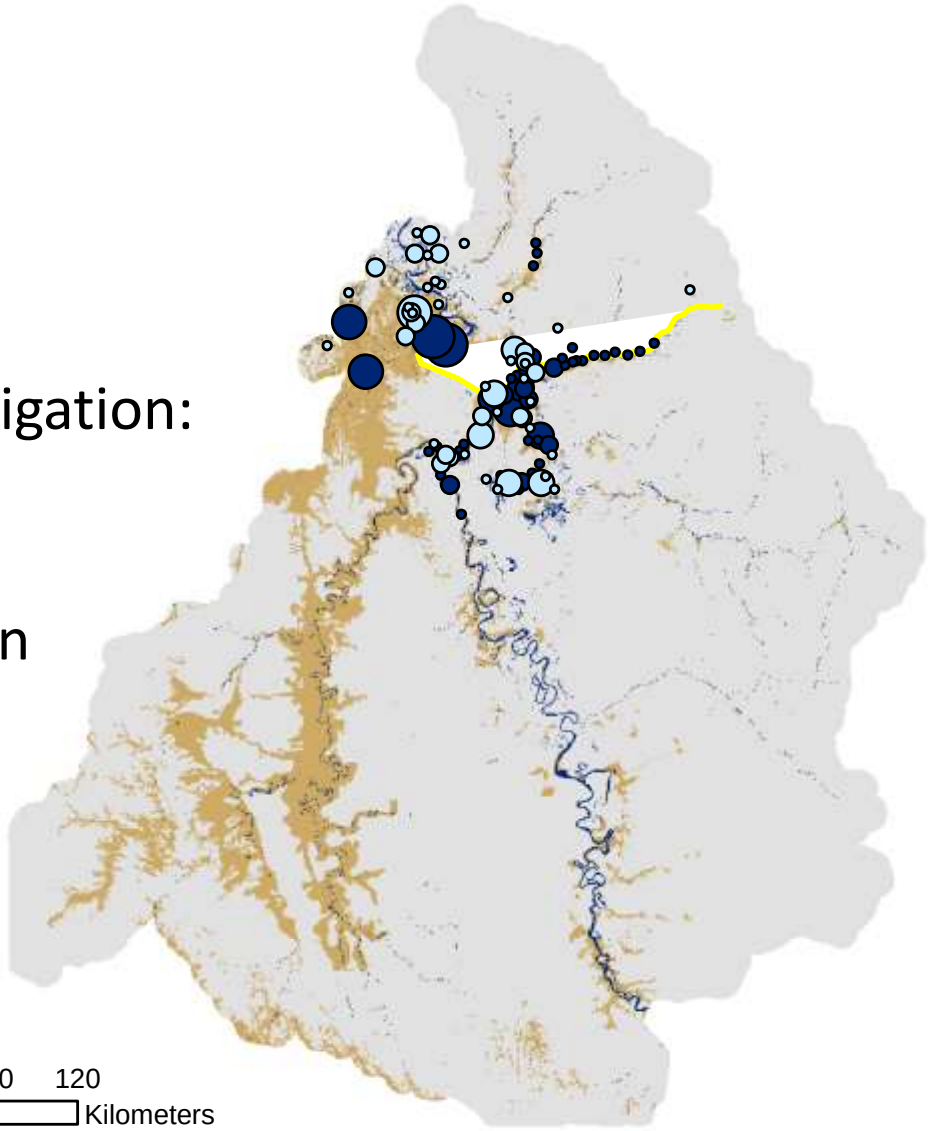
InVEST models for impact & mitigation:

Carbon storage

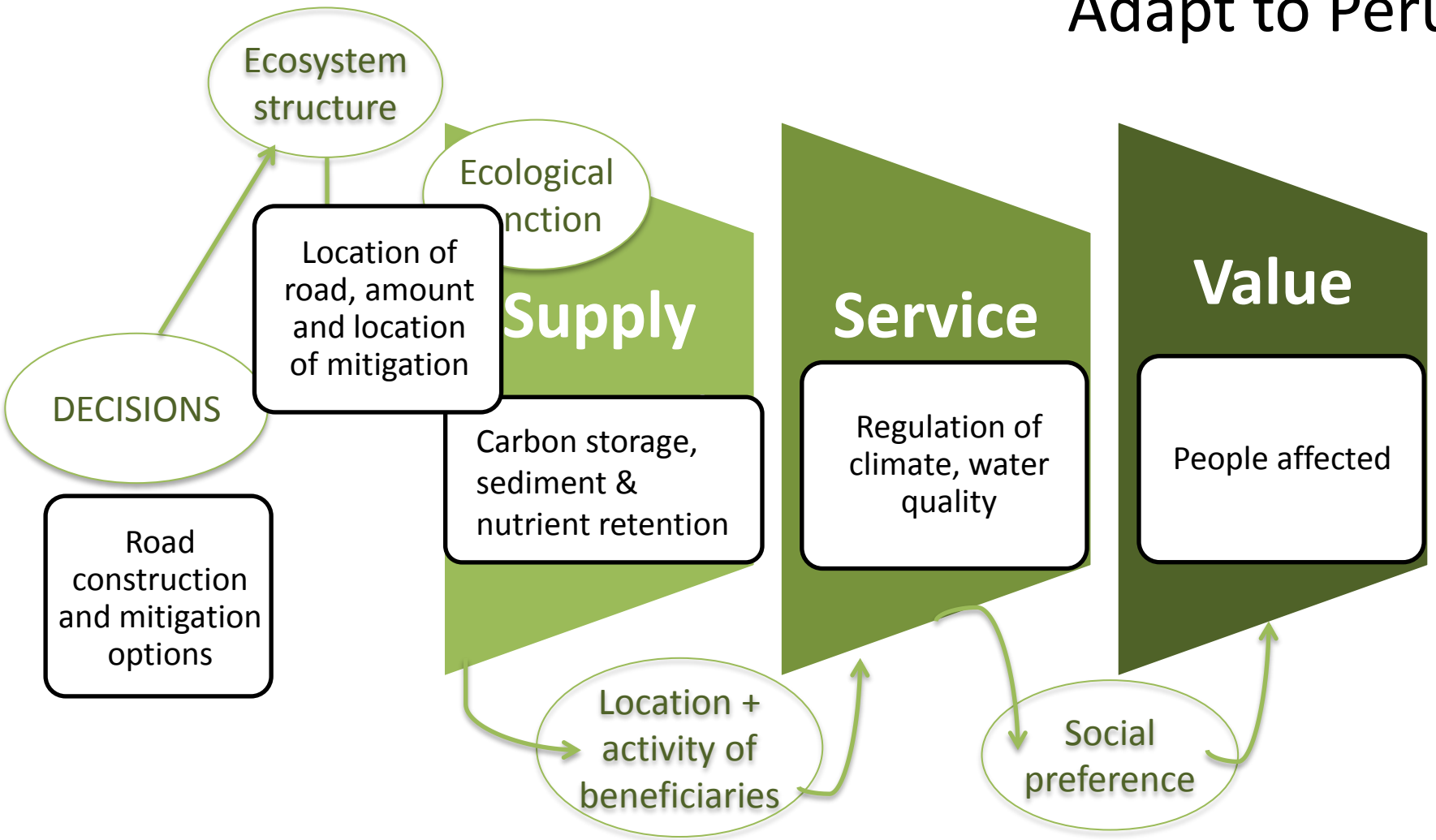
Erosion control

Drinking water quality regulation

- Nitrogen
- Phosphorus



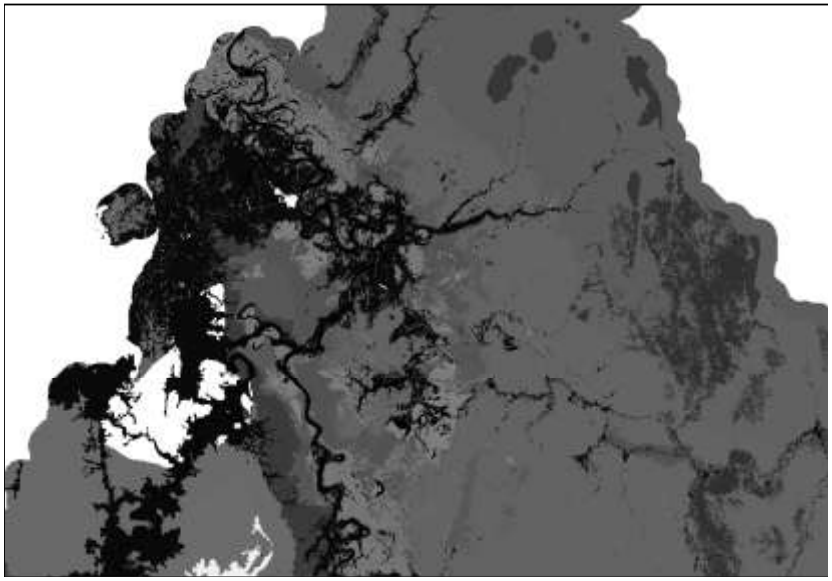
The Natural Capital approach



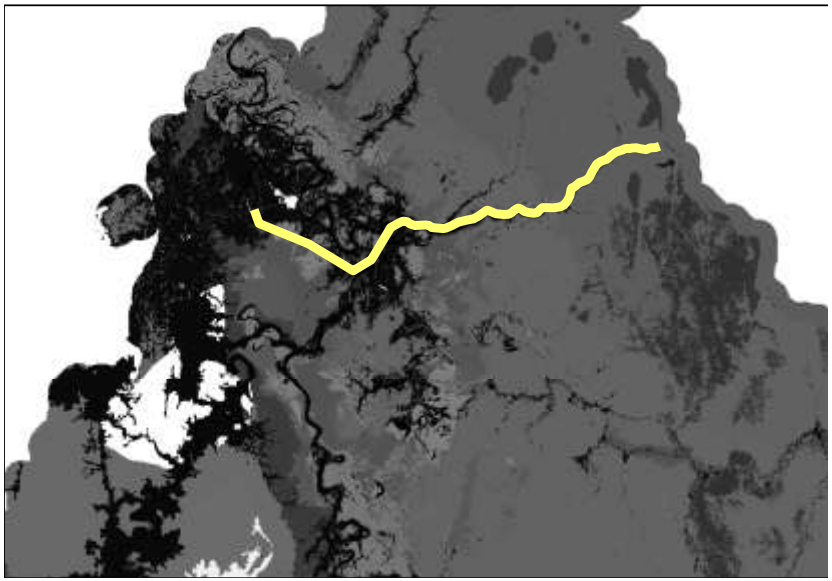
Estimate Impact

SCOPING | IMPACT | MITIGATION

Current LULC



Current + Road

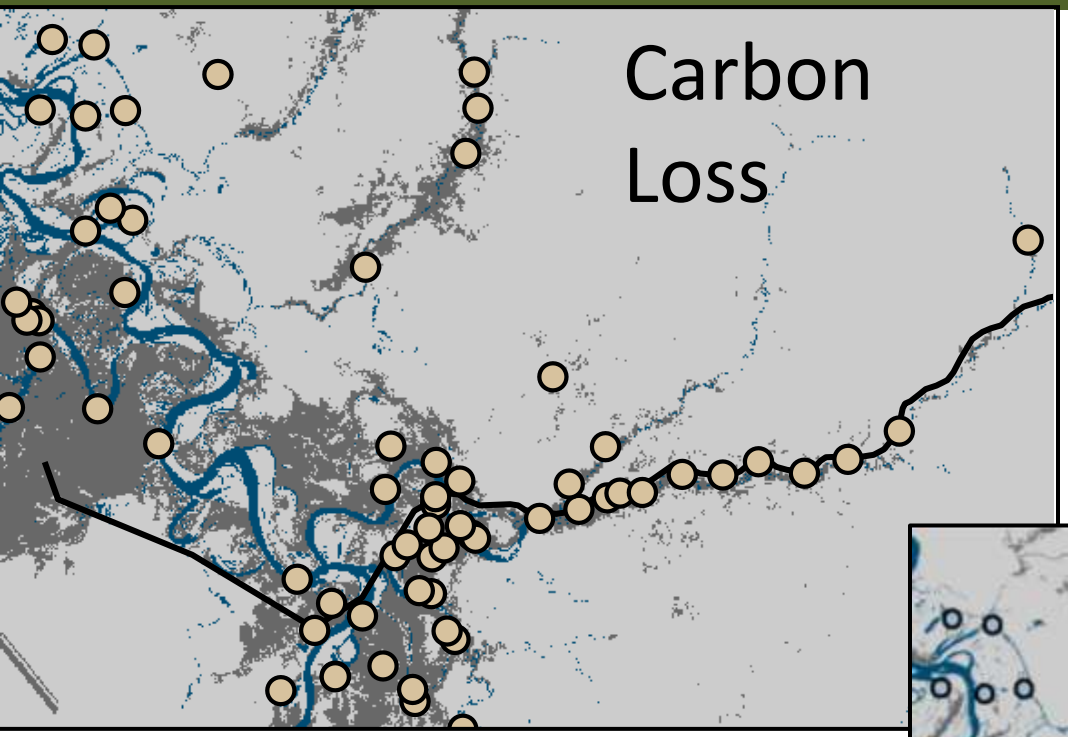


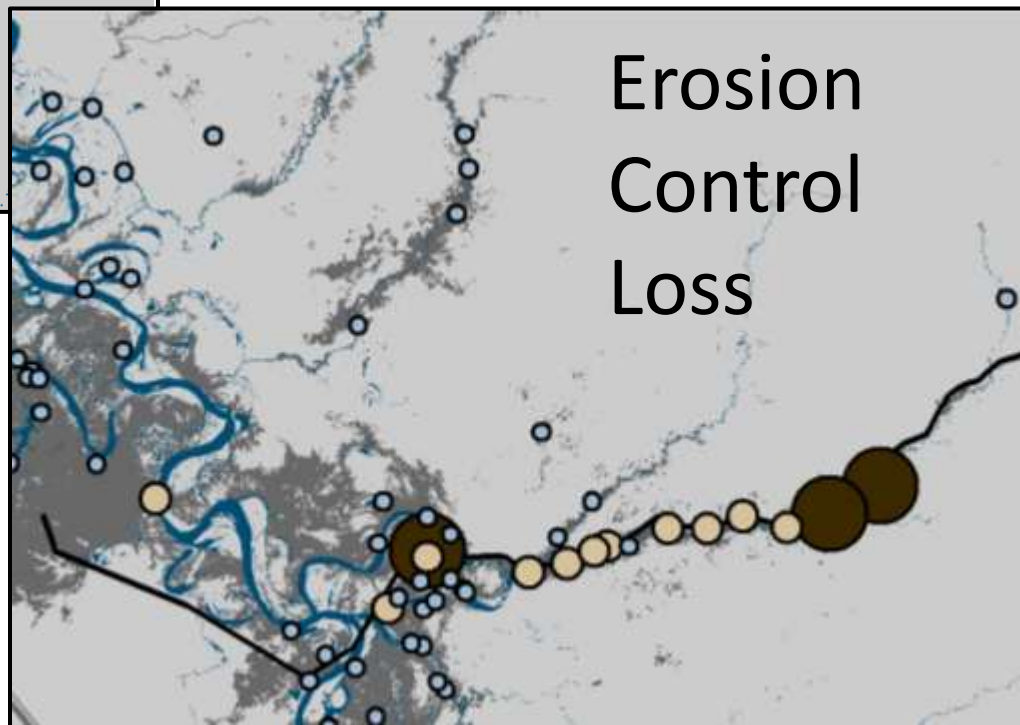
Road impact

InVEST Tier 1 Tools

Estimate Impact

SCOPING | IMPACT | MITIGATION



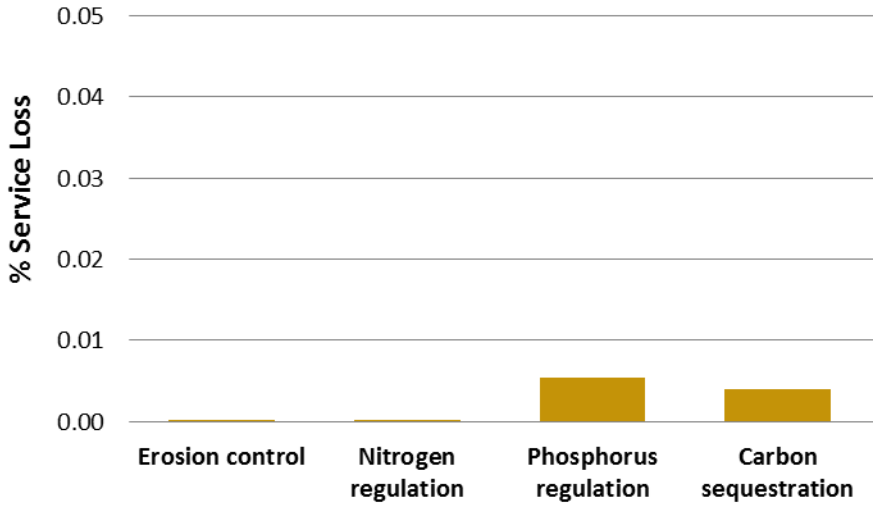


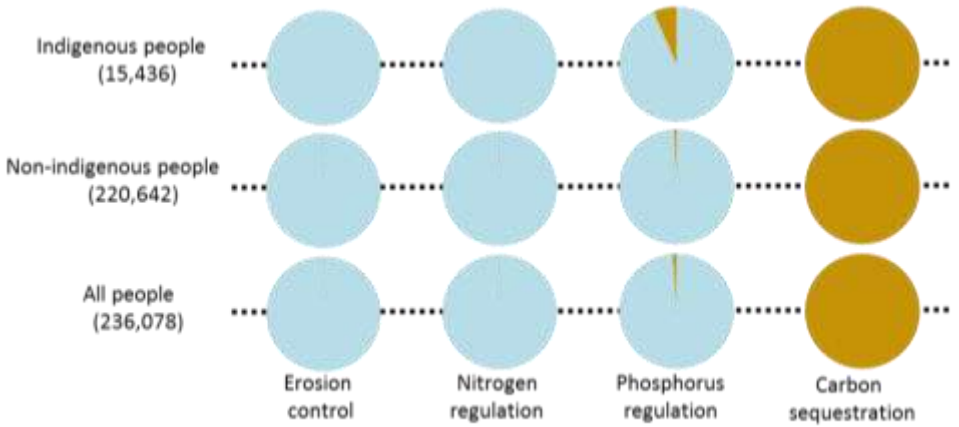
- No change/improved service
- < 0.2% loss
- 0.2-0.4% loss
- 0.4-0.6% loss
- 0.6-0.8% loss

Estimate Impact

SCOPING | IMPACT | MITIGATION

How much is lost? & Who loses?



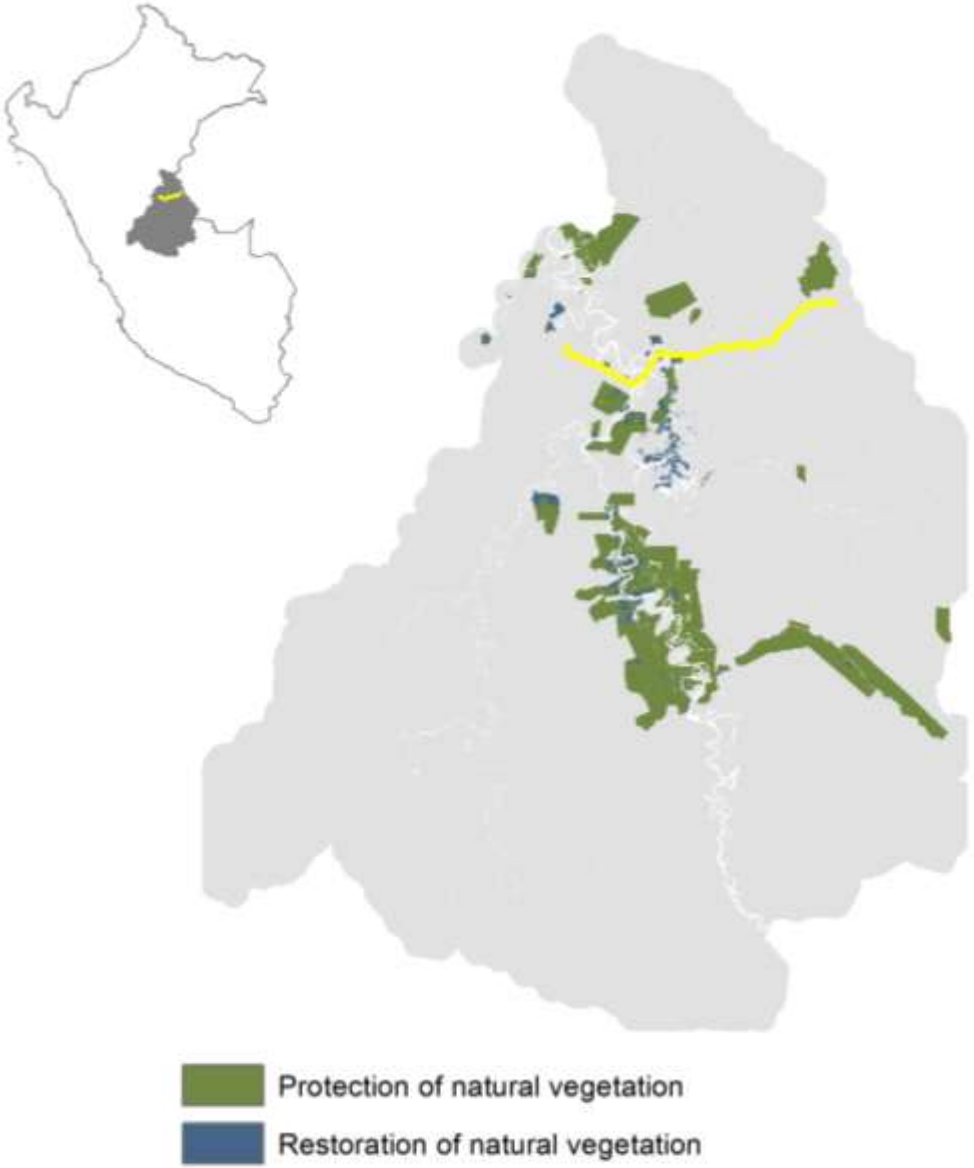


Mitigation

SCOPING | IMPACT | MITIGATION

Can mitigation offset road impacts?

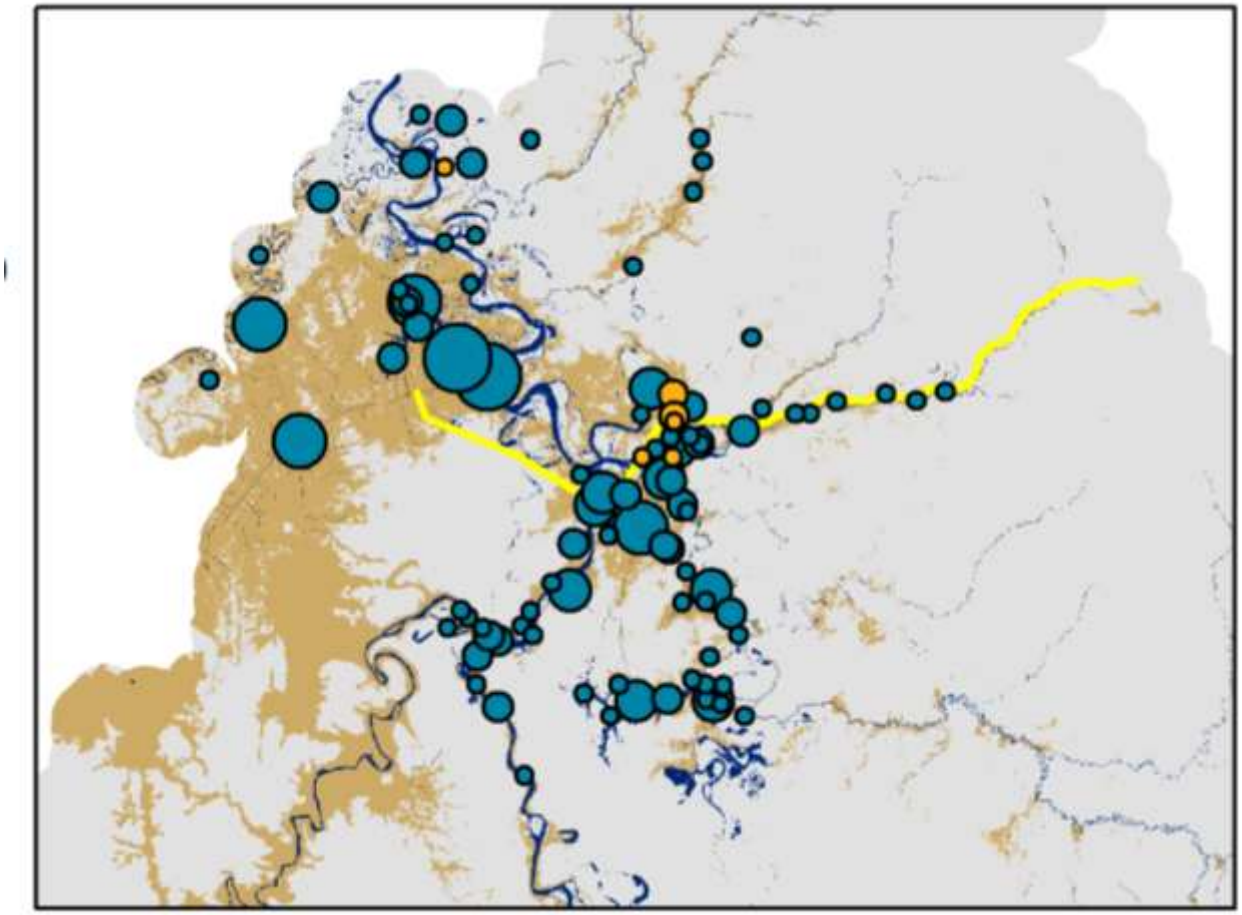
If not, who remains affected?
By how much?
And where?



Mitigation

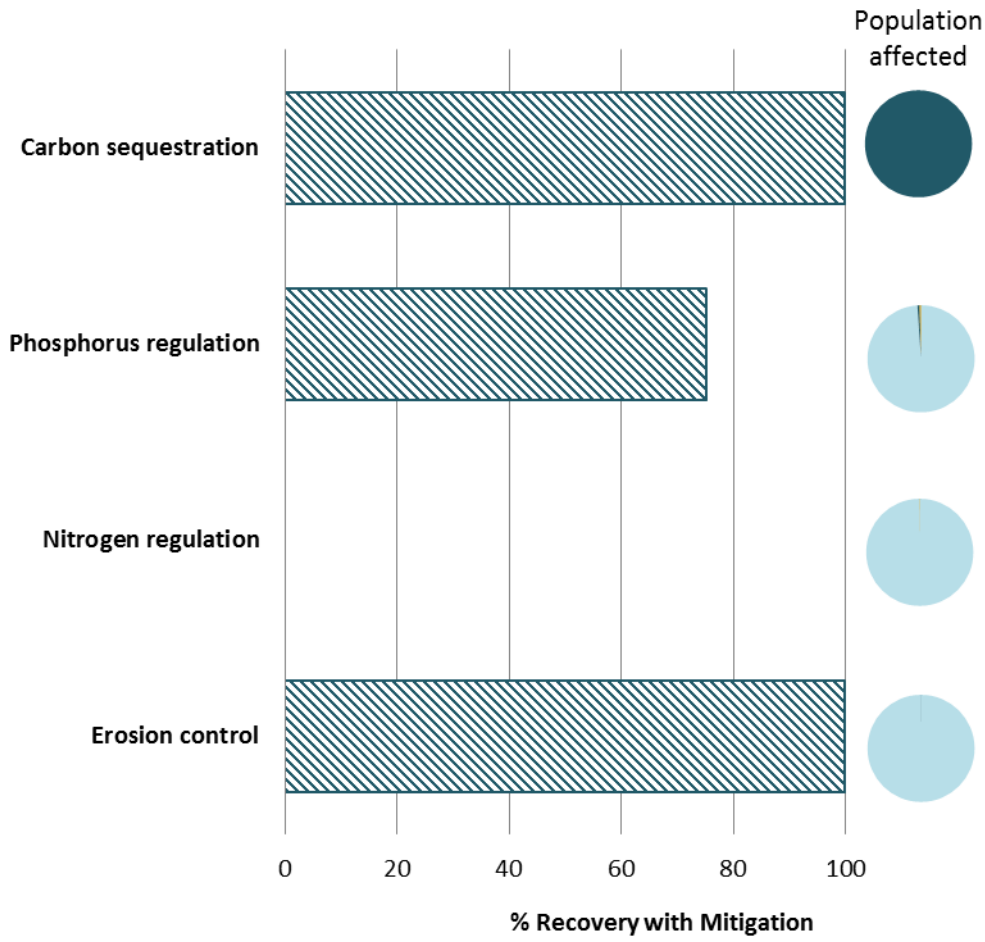
SCOPING | IMPACT | MITIGATION

Where is no net loss possible? And where not?



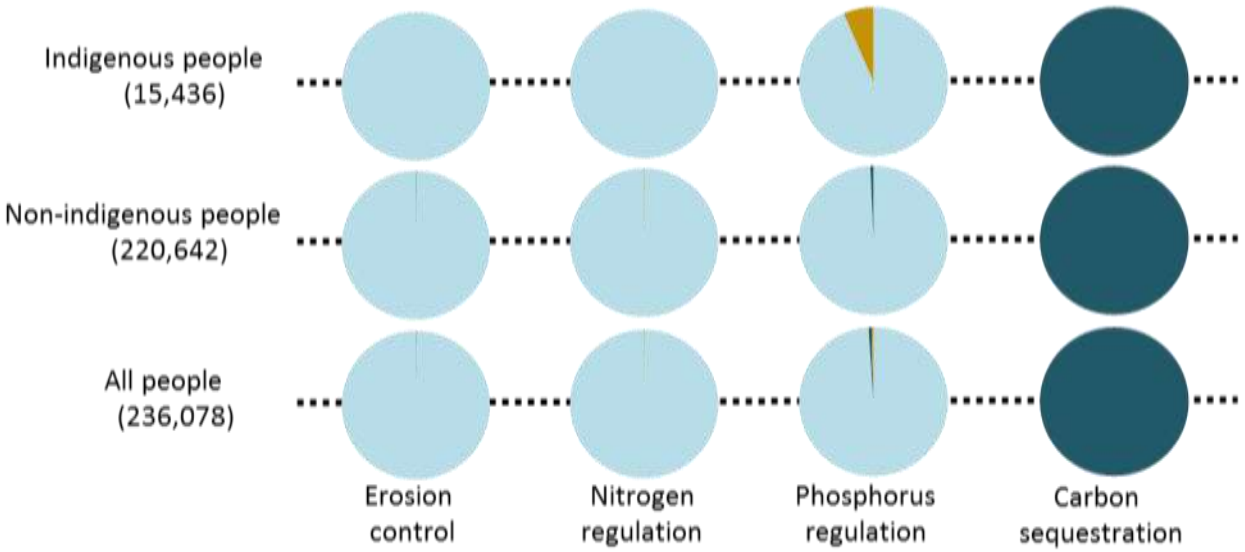
Mitigation

How much mitigation is possible?



Mitigation

Who wins and who loses after mitigation?



More possibilities:

- What additional areas should be priorities for mitigation?
- What are the impacts of increased deforestation following road construction?
- What are the impacts of road development on flood mitigation or non-timber forest products? (InVEST models coming soon)

Resources

www.naturalcapitalproject.org

- NatCap annual meeting/training @ Stanford, Mar. 13-15 – register by Feb. 18
- Download latest version of InVEST
- Watch model training videos

… and more

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