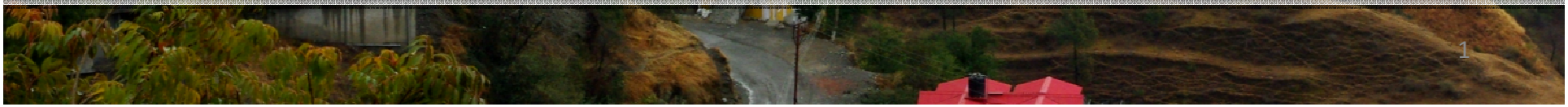
Valuing Ecosystem Services: InVEST Tools

Adrian L. Vogl, Ph.D.
The Natural Capital Project, Stanford University
avogl@stanford.edu




natural
capital
PROJECT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FOR THE ENVIRONMENT
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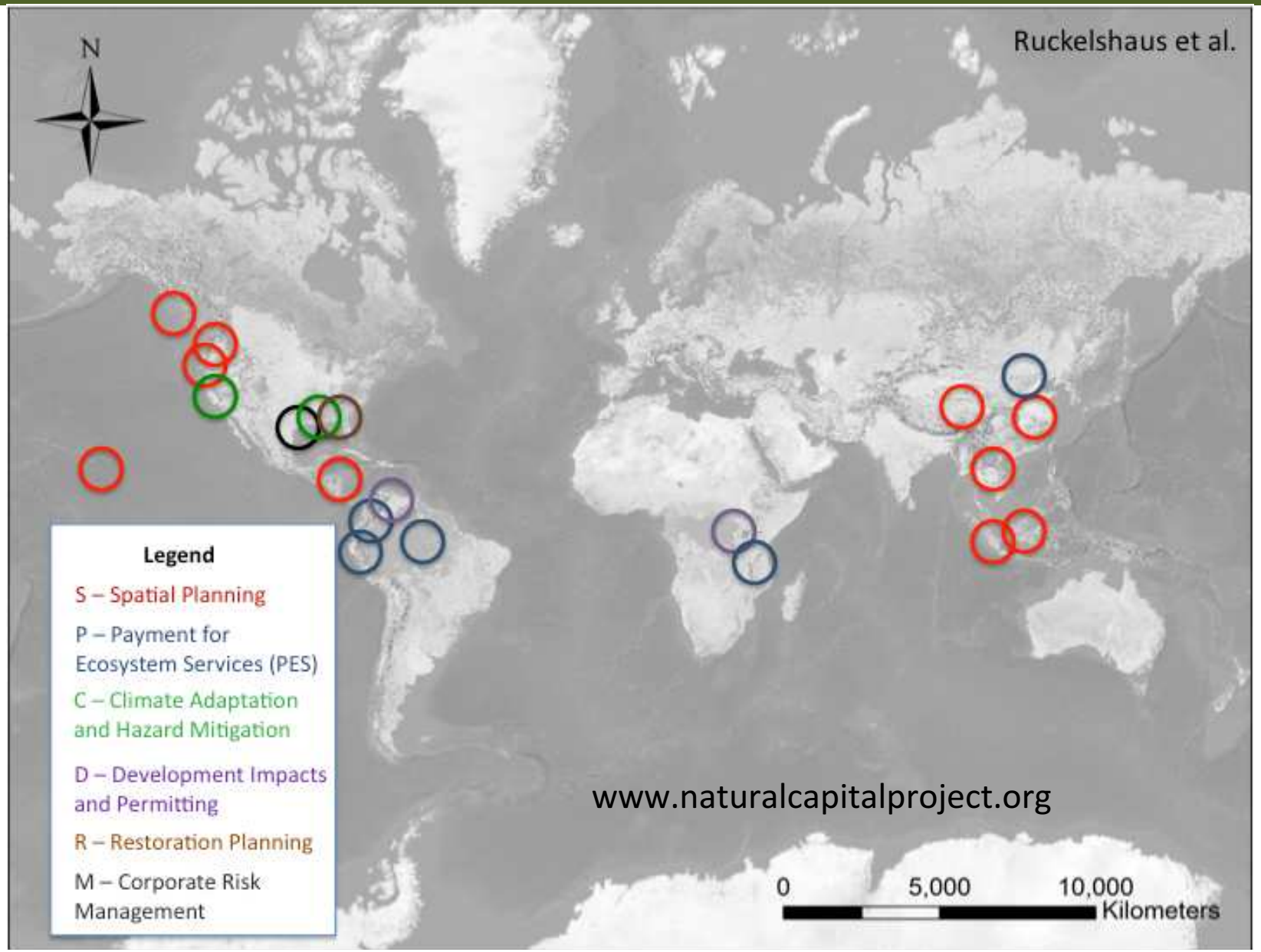
WWF


The Nature
Conservancy

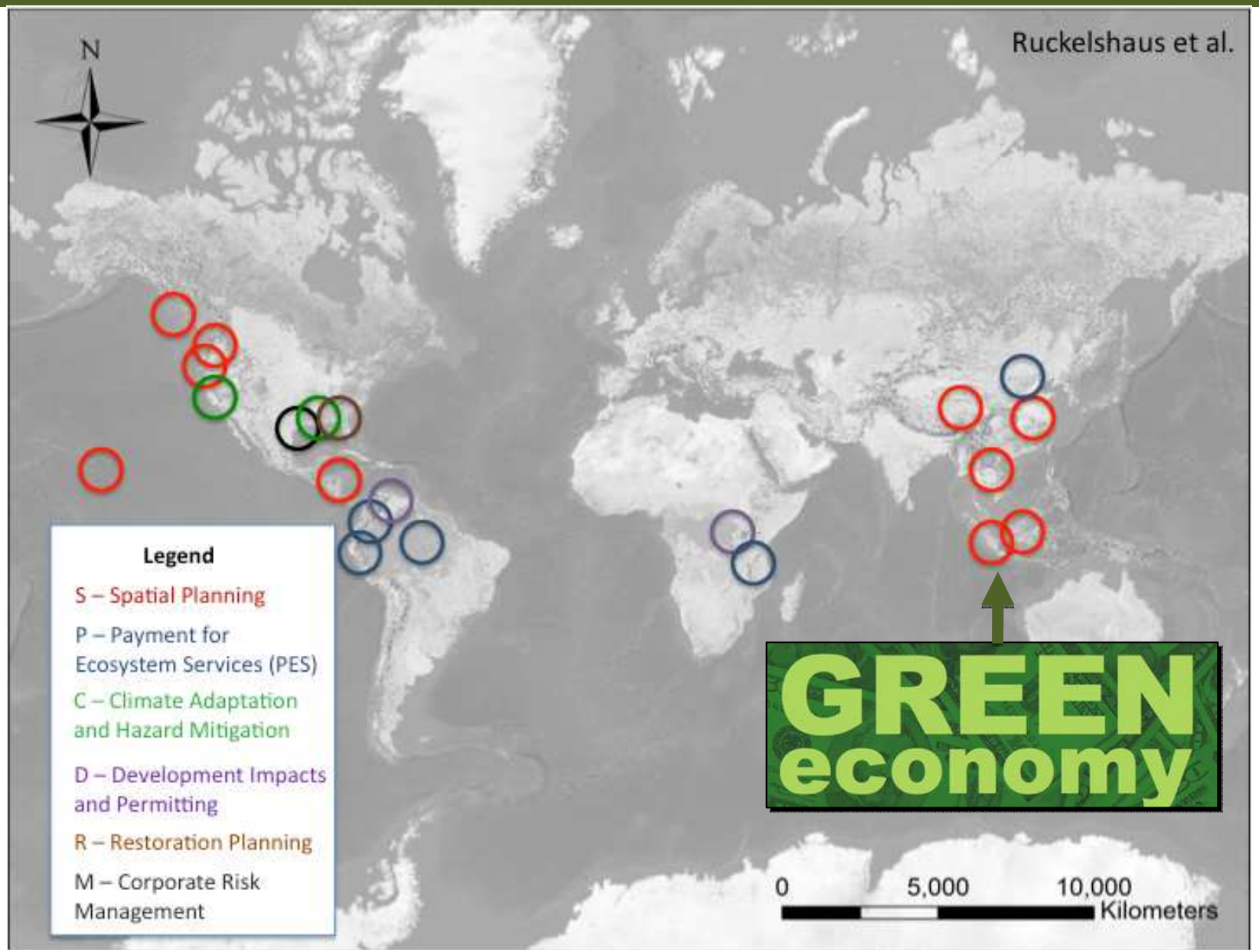

INSTITUTE ON THE
ENVIRONMENT
UNIVERSITY OF MINNESOTA
Driven to Discover℠

What is the Value of Nature?

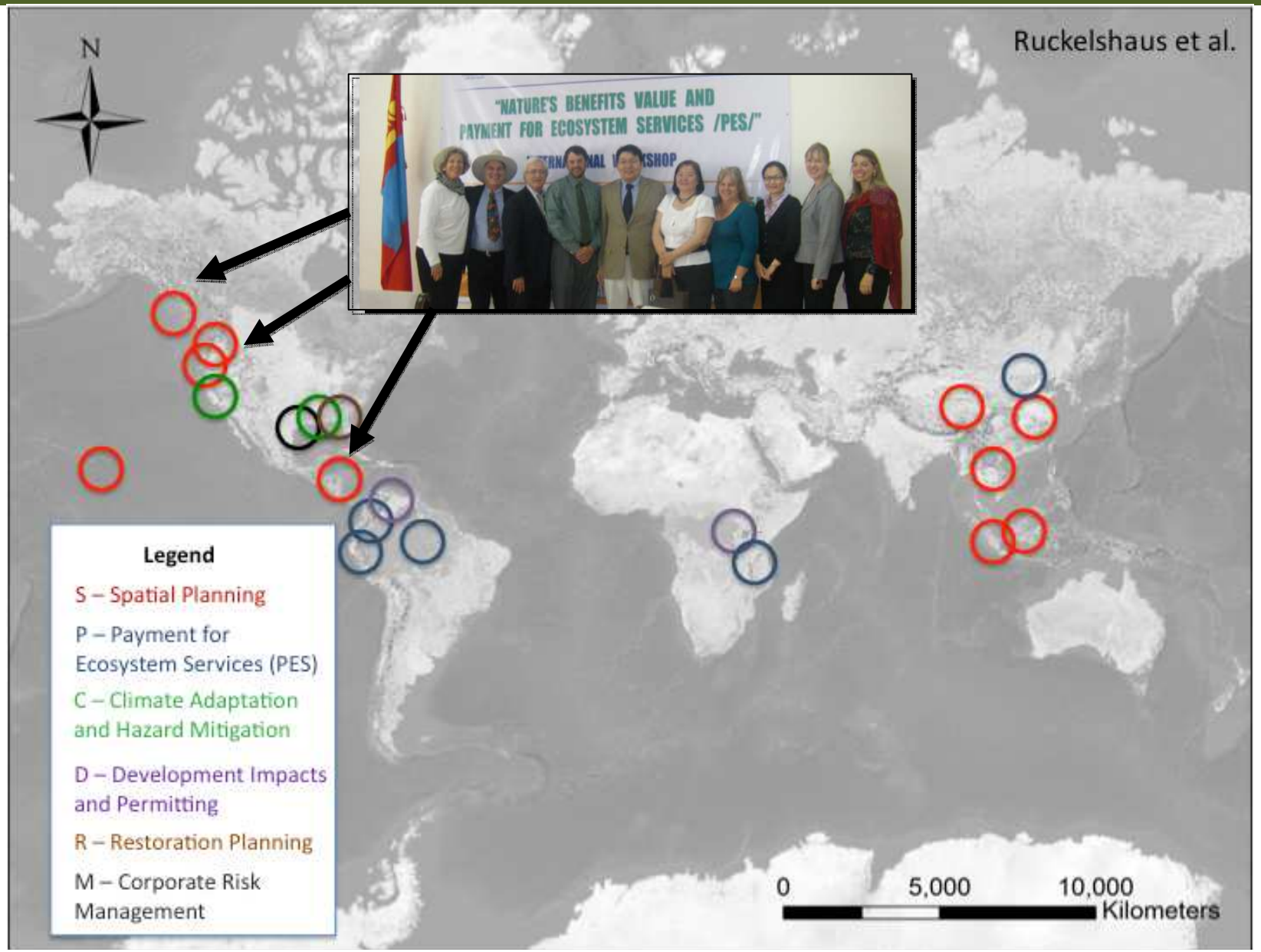
Valuing Nature in Decisions



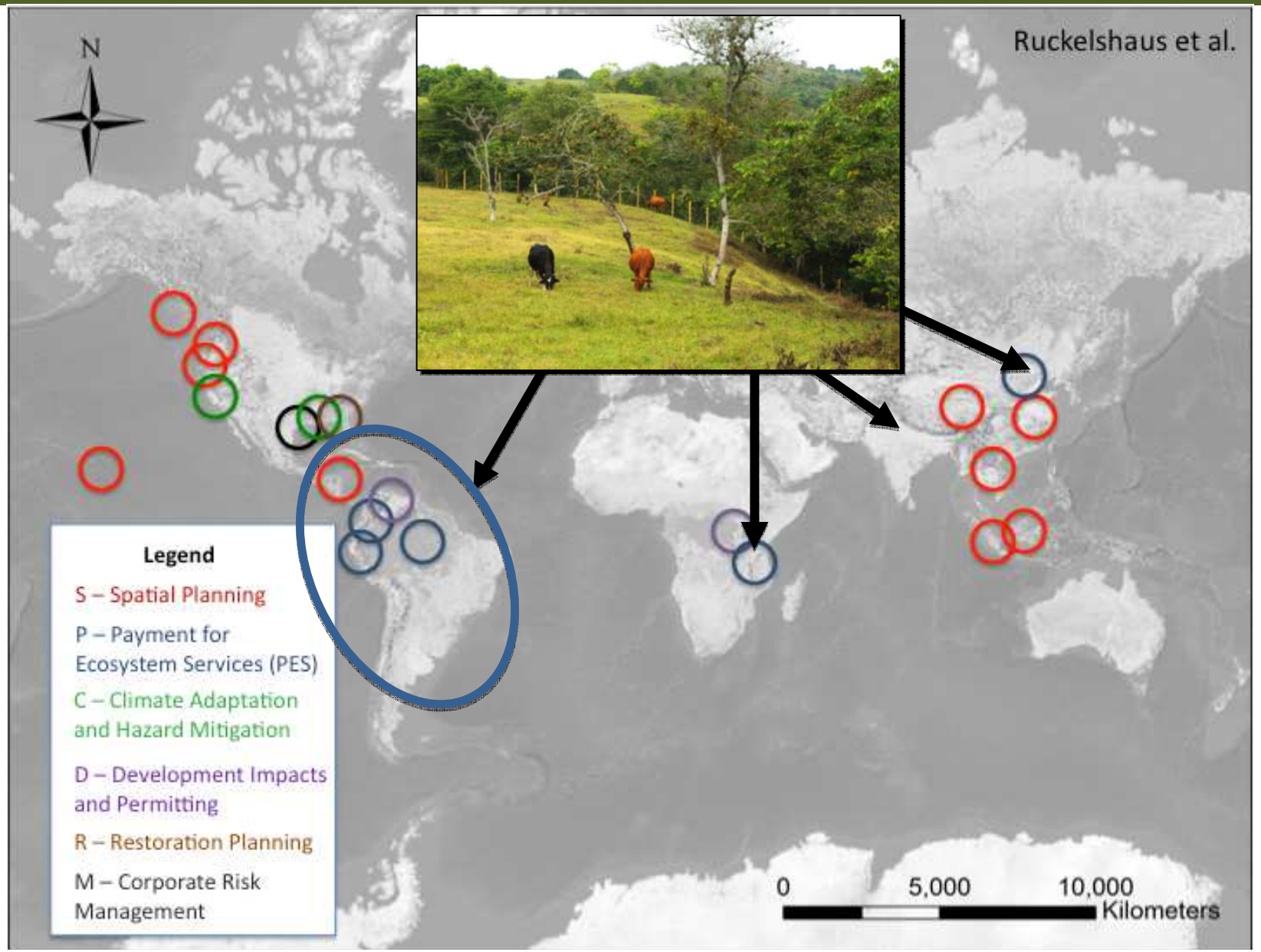
What policies can help promote green growth?



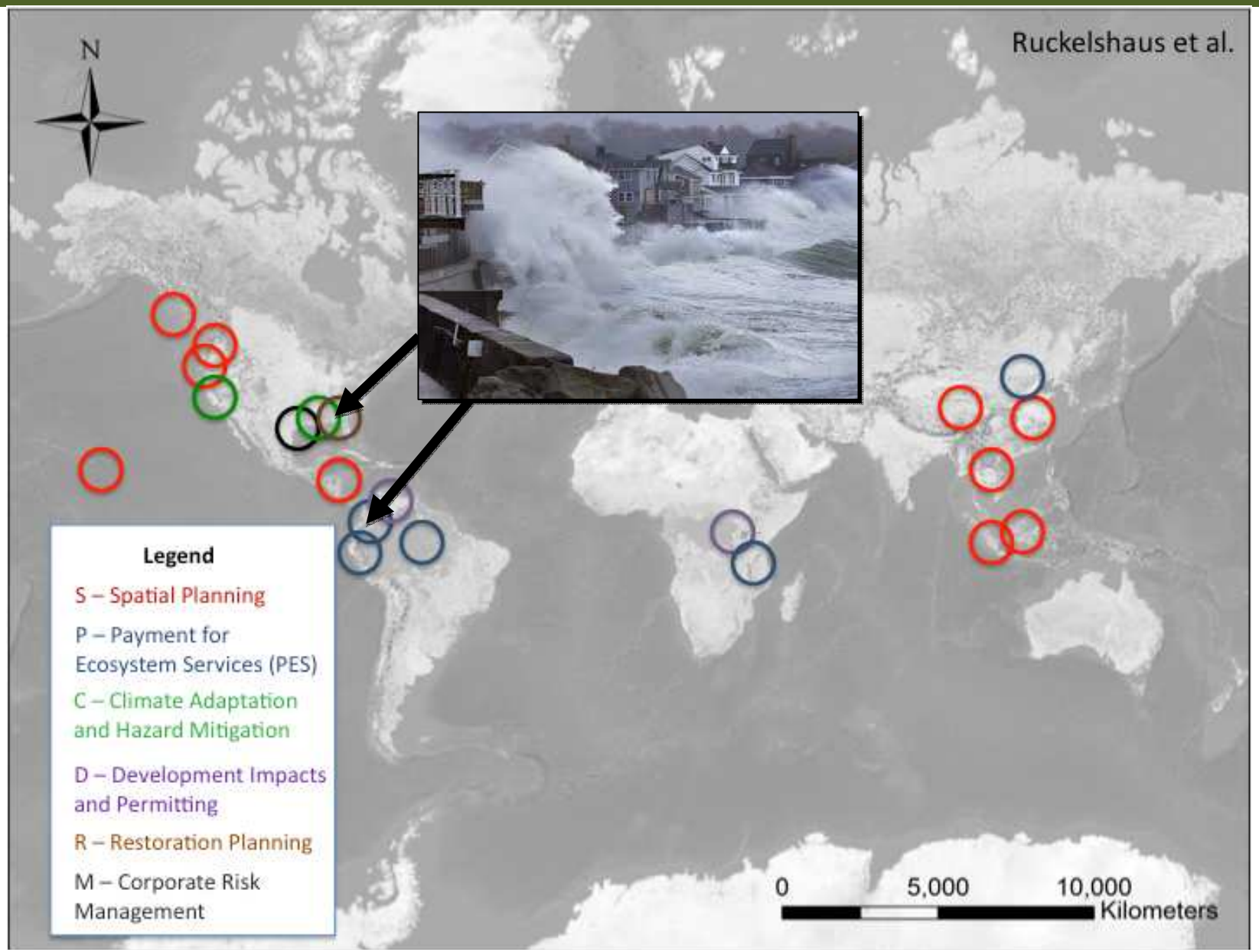
How do you get multi-agency cooperation?



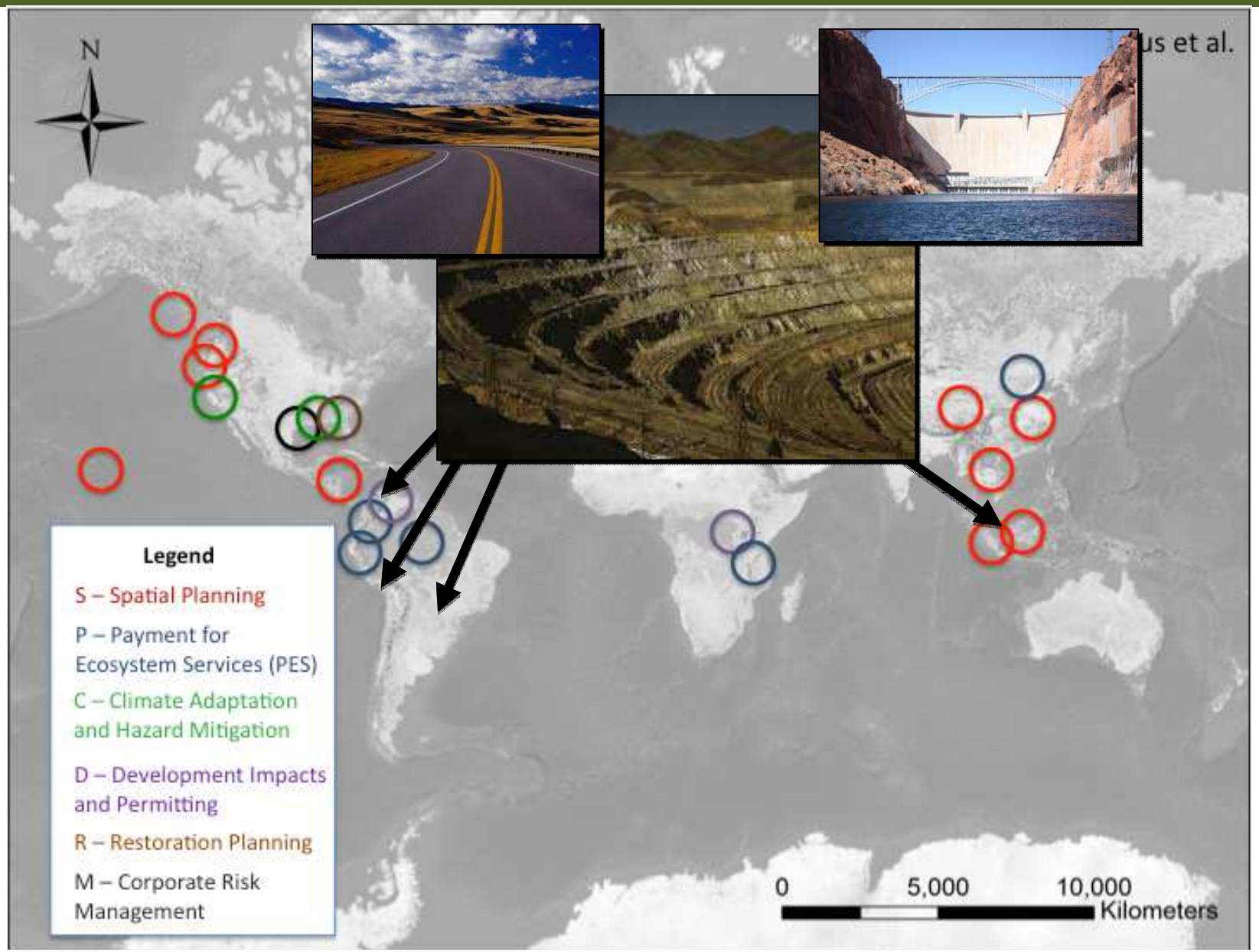
How do you design efficient incentives?



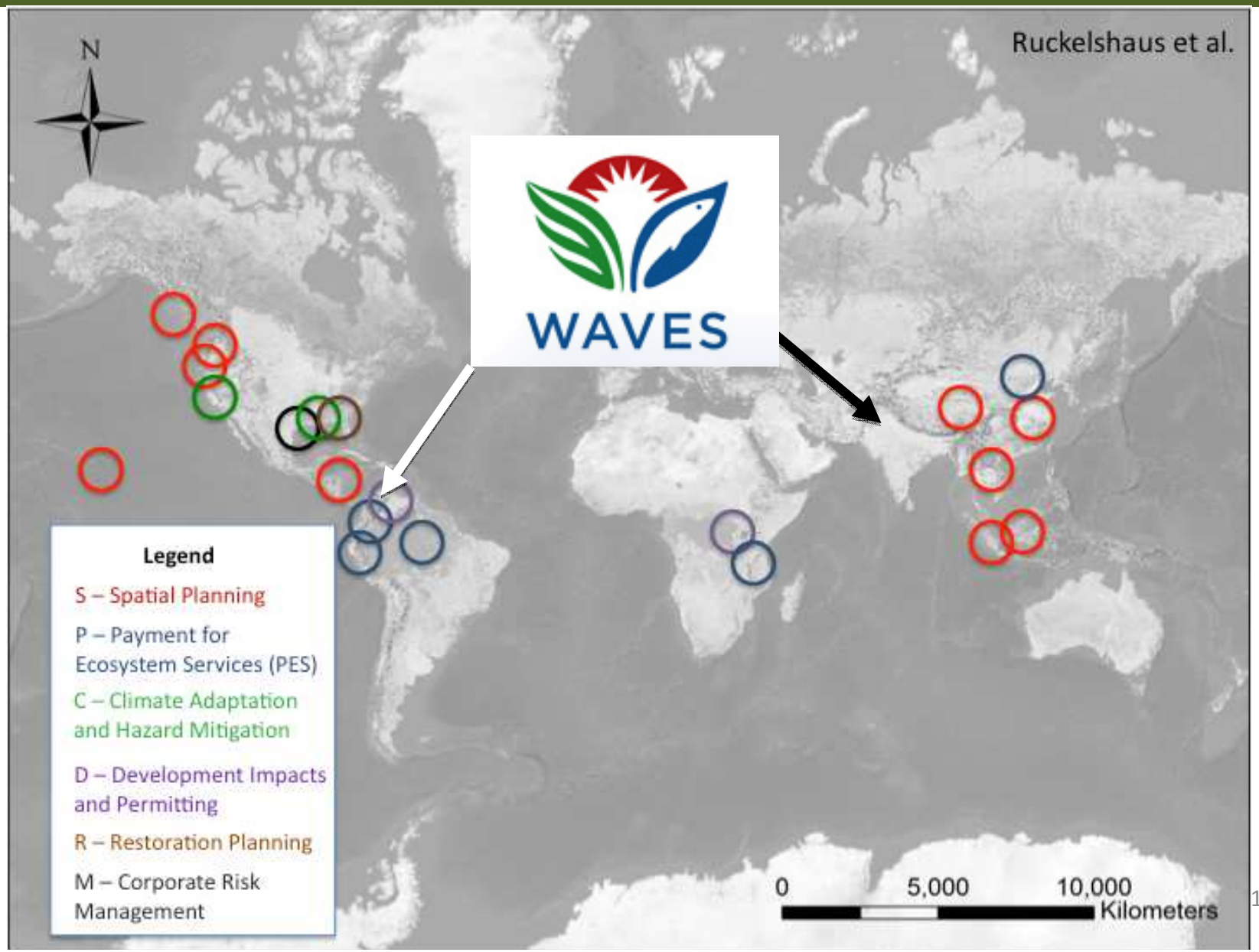
How can communities adapt to climate change?



Which companies or projects meet safeguards?



How can we improve national accounts?



The Natural Capital Approach: Tools

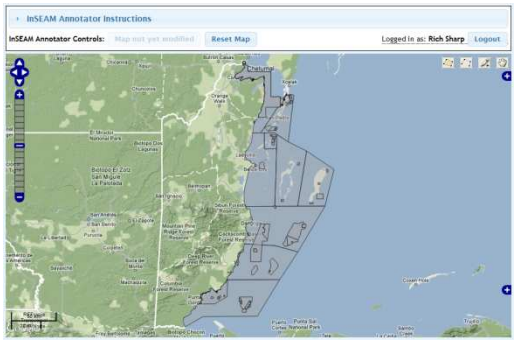
InVEST

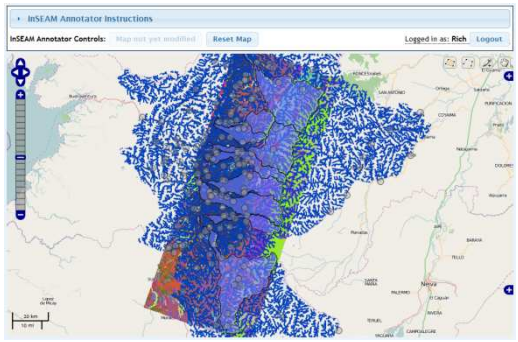
integrated valuation of environmental services and tradeoffs

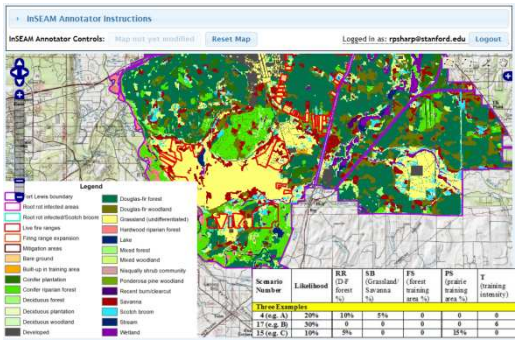
RIOS

resource investment optimization system

InSEAM – InVEST Scenario Modeler







InVEST

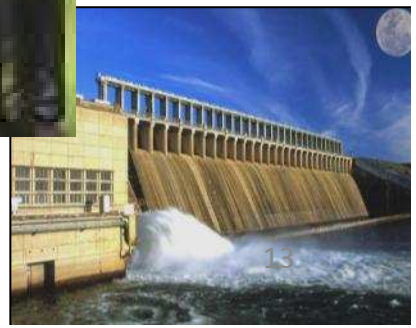
Map, quantify and value multiple ecosystem services

Spatially Explicit Ecological Production Functions

Ecological Production Function- an equation that relates the physical outputs of a production process to physical inputs





InVEST Model Structure

Supply → Service ⇢ Value

Ecological functions
Ecosystem elements

Supply
+
Location and activity of beneficiaries

Service
+
Social preference

Why InVEST?

- Applicable across the globe
- Requires easily-available data
- Flexible scale
- Relevant to many kinds of decisions
- Biophysical and economic outputs
- Allows multi-service assessment
- Considers landscape context

Recent Advances

- Freely available – 3.0 Framework ArcGIS-independent
- Uncertainty assessment in carbon model
- Helper tools, Batch scripting
- Scenario generating tools
- Active development community

InVEST Software - Terrestrial

Biodiversity: Habitat Quality

Water yield for hydropower production

Erosion control: reservoirs and WQ

Water purification: nutrient retention

Carbon sequestration & storage

Managed timber production

Crop pollination

Coming Soon – Agricultural Production

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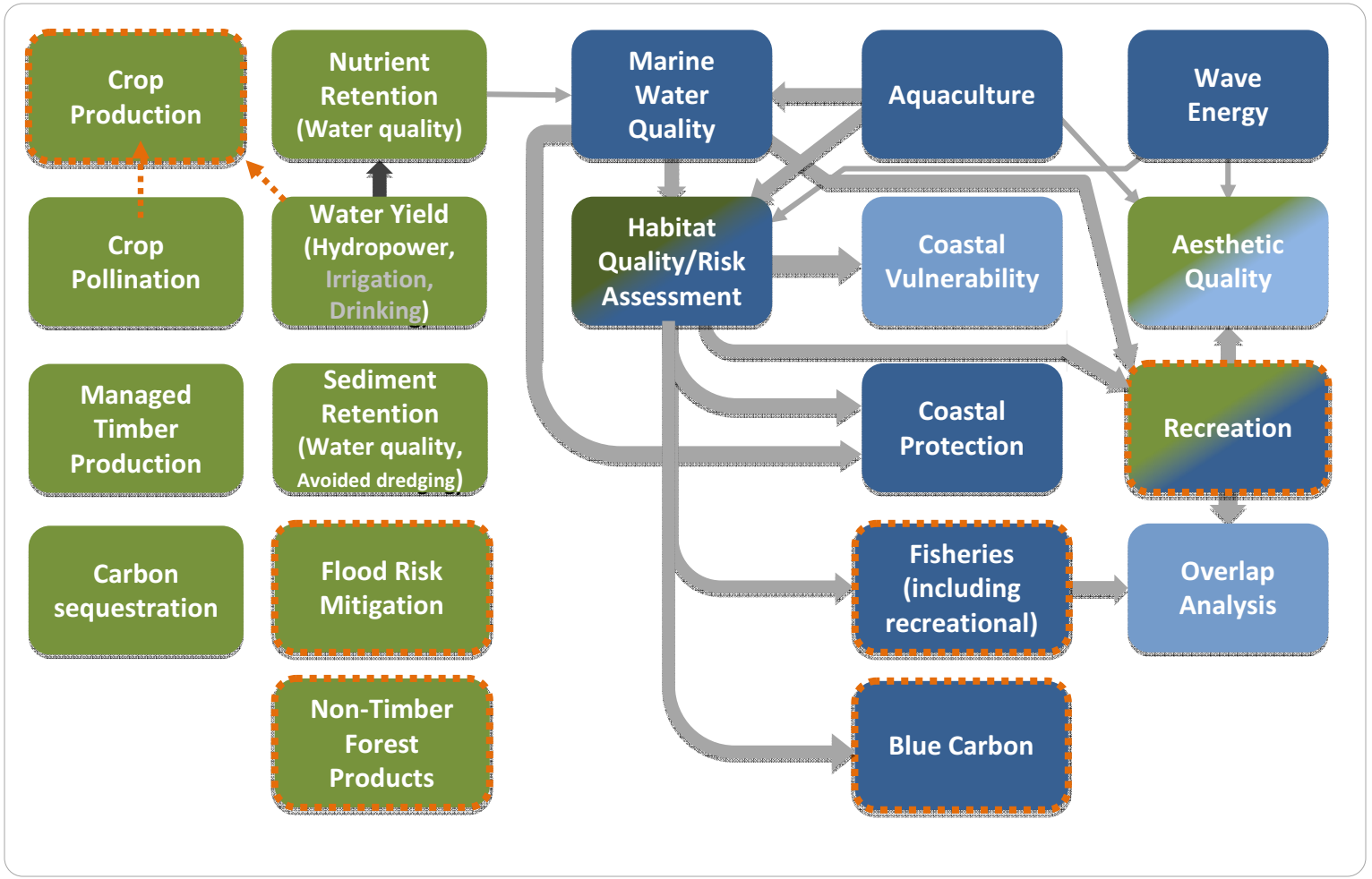
InVEST Models & Linkages



Terrestrial/freshwater model: Tier 0

Terrestrial/freshwater model: Tier 0

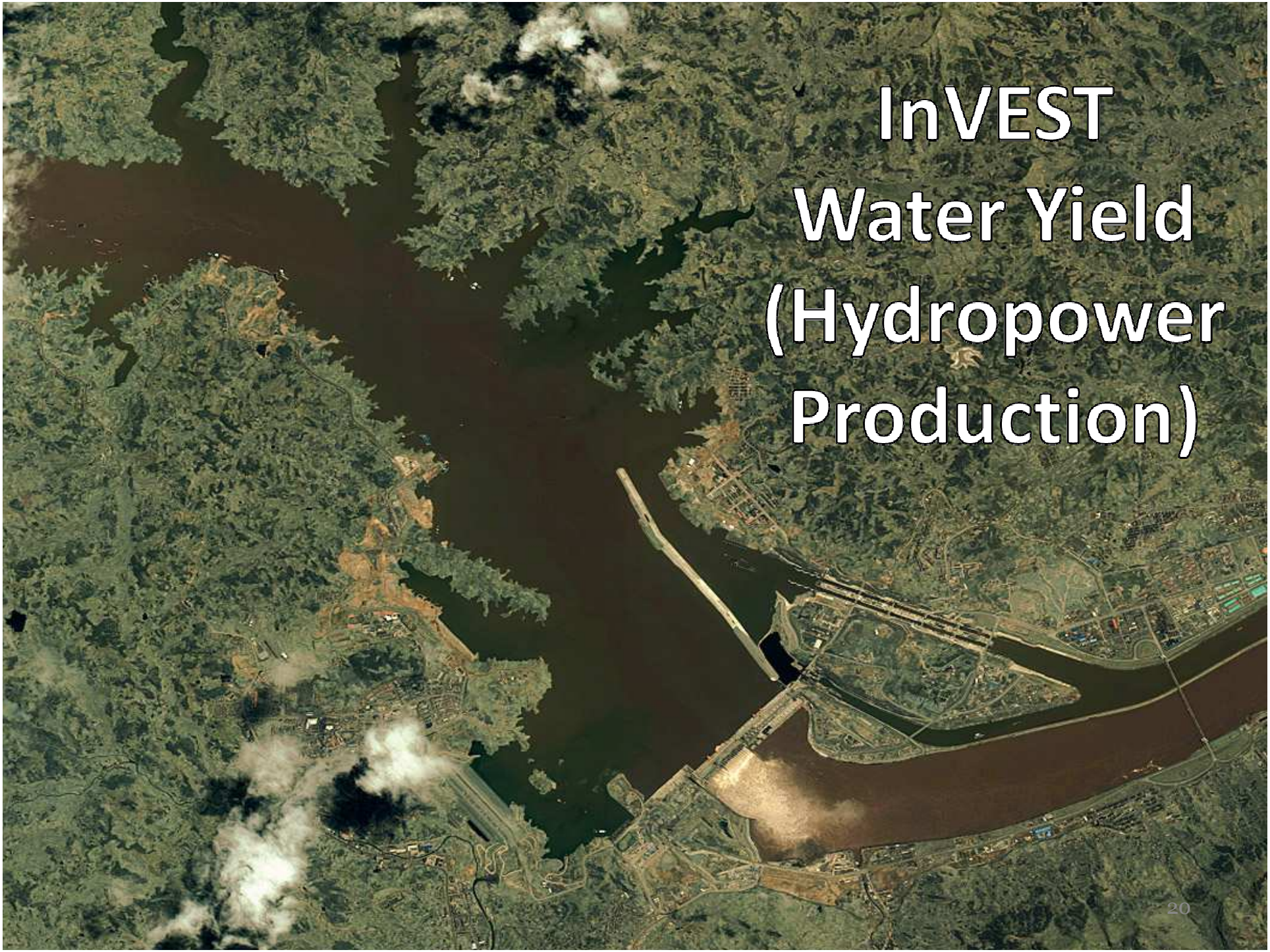
Marine model: Tier 1

Marine model: Tier 0

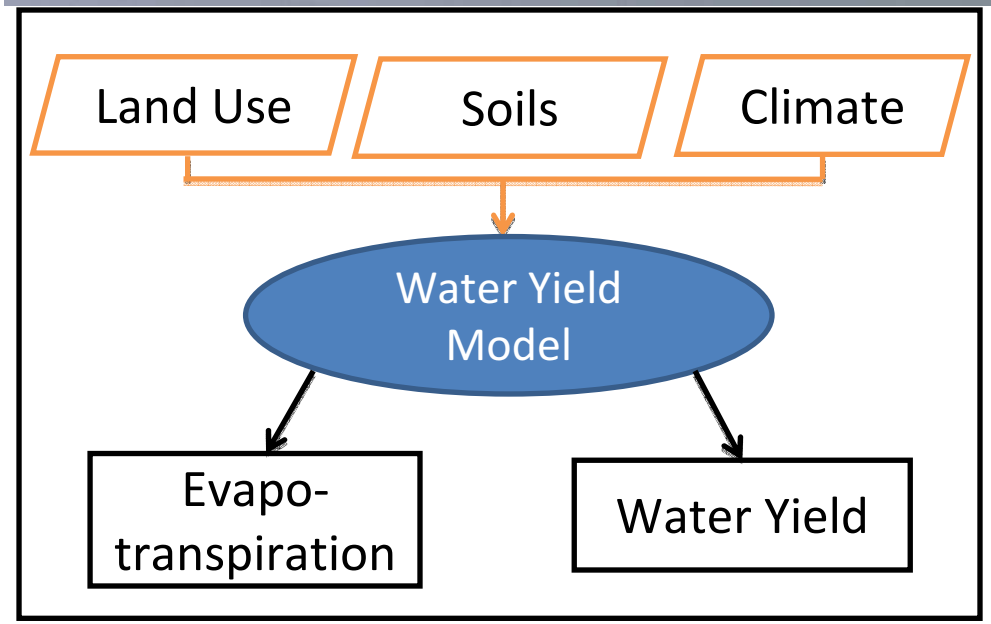
Model coming soon!

Optional model linkage

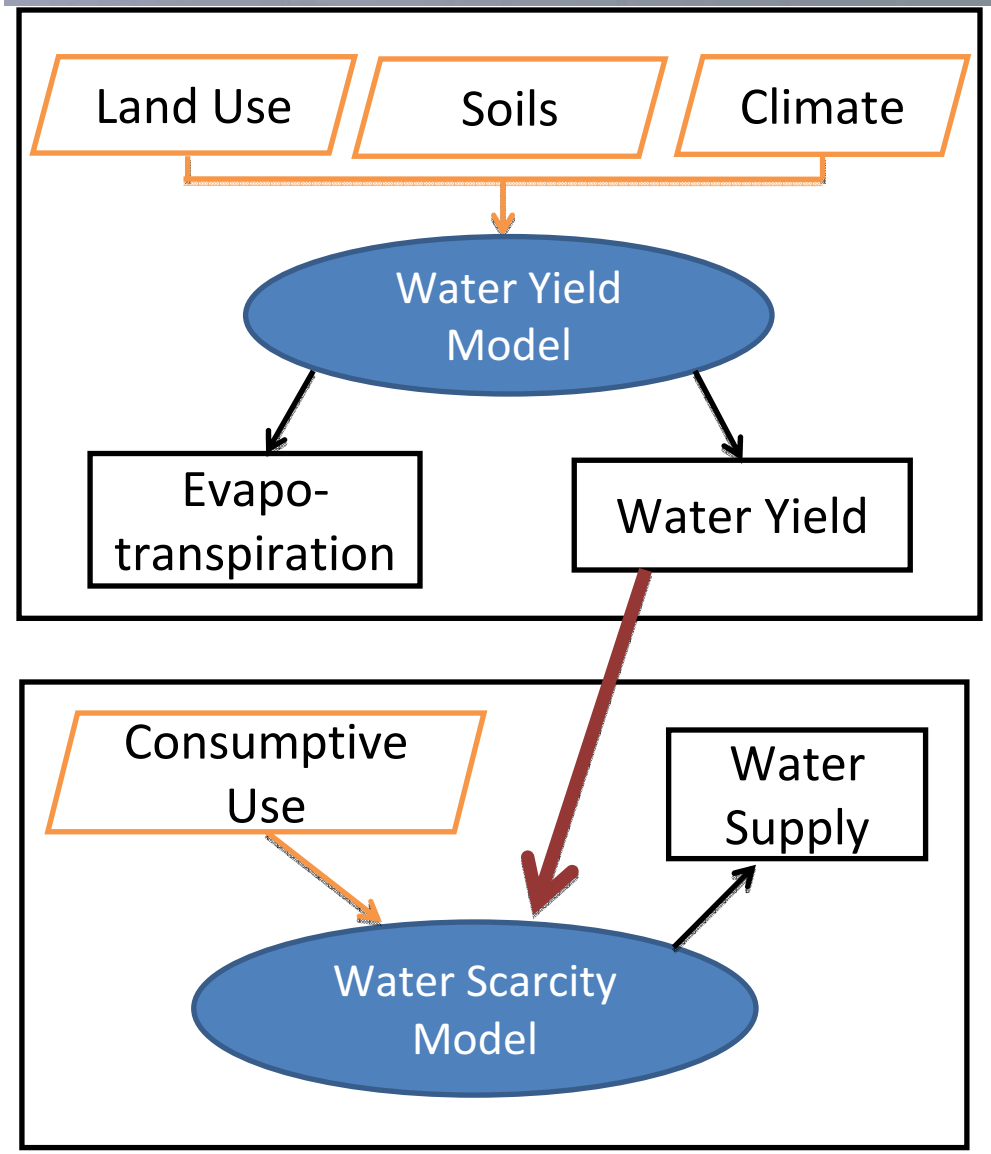
Required model linkage


InVEST
Water Yield
(Hydropower
Production)

Model Architecture



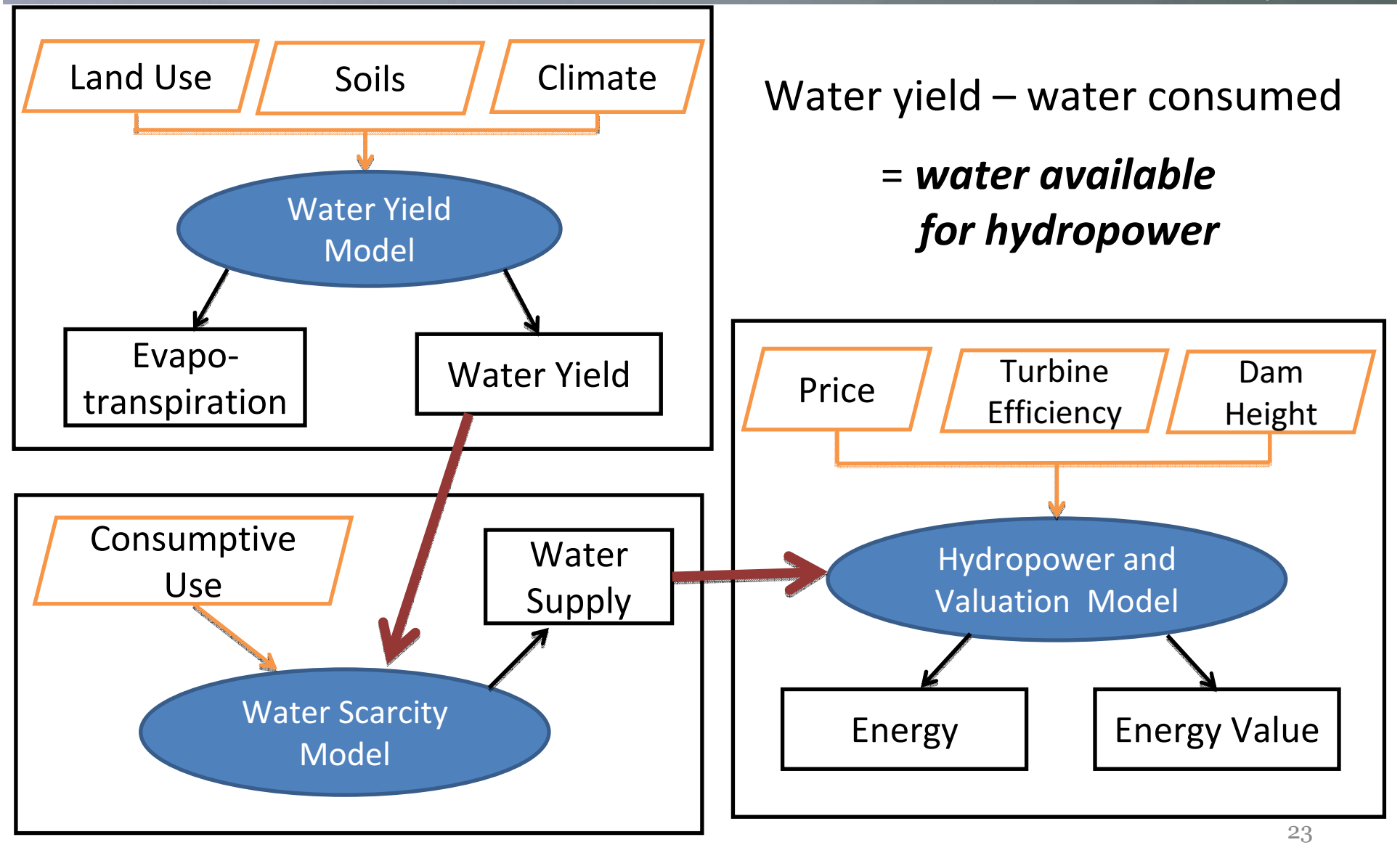
Model Architecture



Water yield – water consumed

= ***water available for hydropower***

Model Architecture



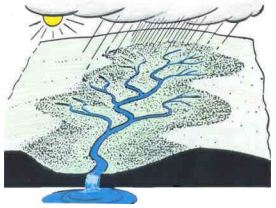
Water yield – water consumed

= ***water available for hydropower***

Model Inputs

Climate

Precipitation, Potential Evapotranspiration, Zhang



Watersheds

Main and sub-watersheds for point of interest

Soils

Soil depth, Plant Available Water Content

Water demand

Land Use/Land Cover

Root depth, Evapotranspiration coefficient

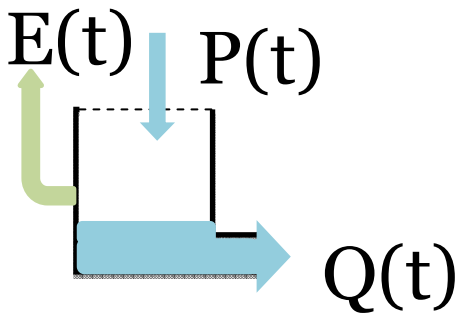
Economic

Hydropower plant data, price of energy

Equations – Water Yield

- Water Yield is the water depth (volume) that is NOT Evapotranspired: *WY = P – AET*
- It is the sum of Surface flow, subsurface flow and groundwater flow:

  WY = SR + SubSR + GW
- Model: ***WY = P * (1 – AET / P)***



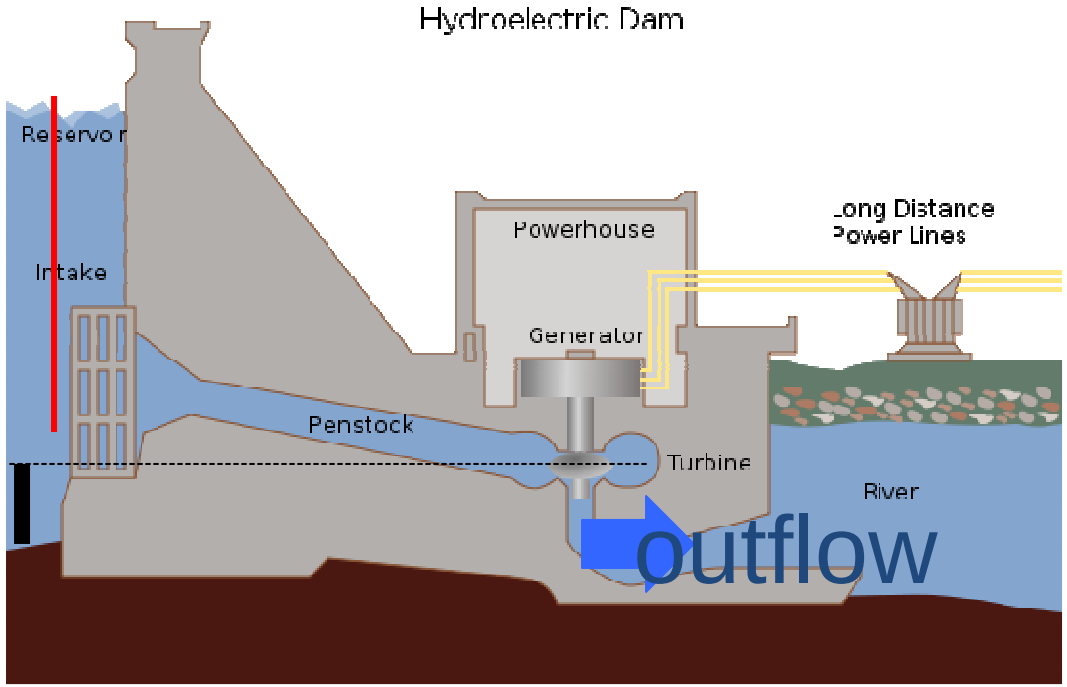
$$\frac{AET_{xj}}{P_x} = \frac{1 + \omega_x R_{xj}}{1 + \omega_x R_{xj} + \frac{1}{R_{xj}}}$$

where

$$\omega_x = Zhang \frac{AWC_x}{P_x}$$

$$R_{xj} = \frac{kc \cdot ETo_x}{P_x}$$

Energy production and value



- Energy produced
- Total value of hydropower produced
- Sub-basin value for power produced

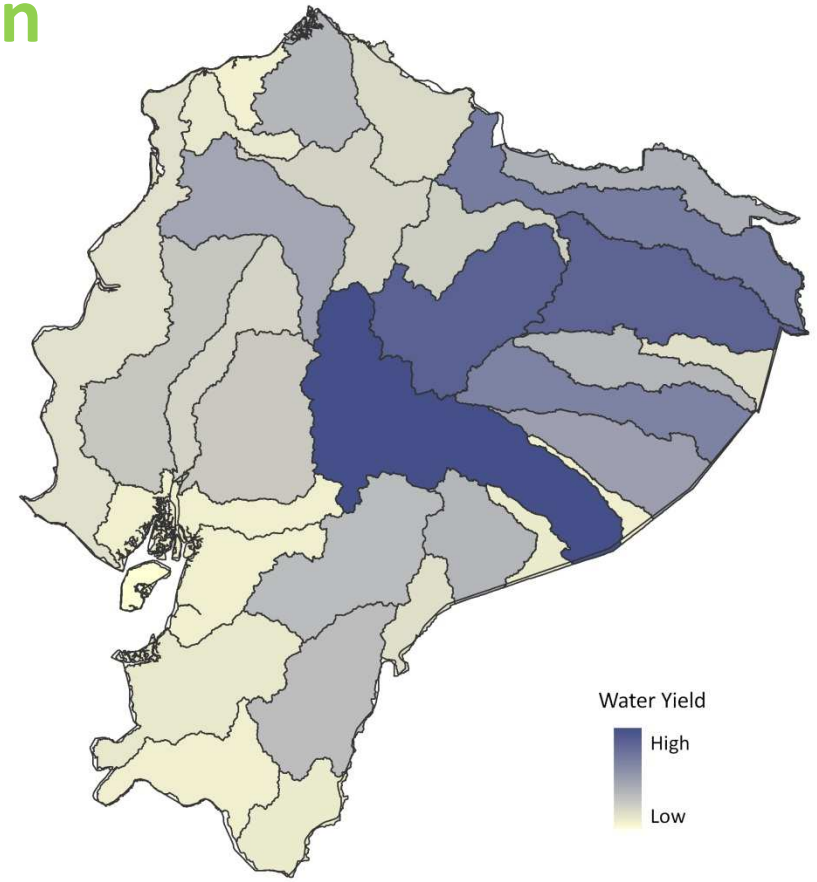
Model Outputs

- **Actual Evapotranspiration**
  mm/year

- **Water yield**
  mm/year

- **Water supply**
  m^3/year
  Used in valuation

- **Energy/value for hydropower**
  Kw/currency over timespan

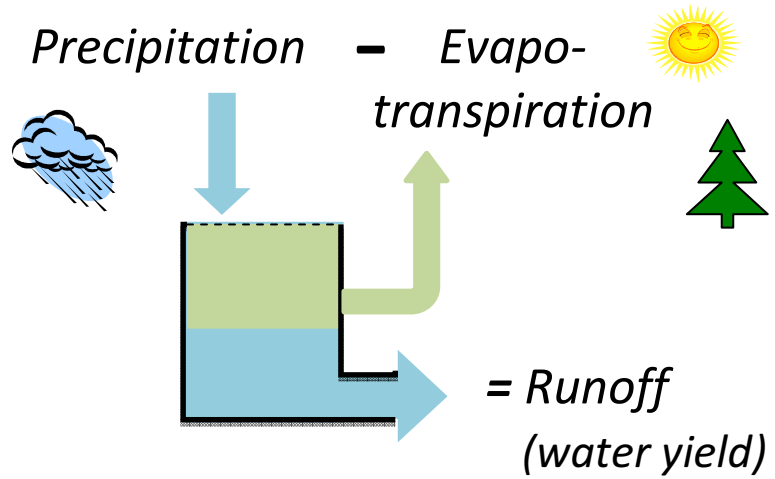



InVEST
Nutrient and
Sediment
Retention

Nutrient Retention Model

Based on runoff and export coefficients

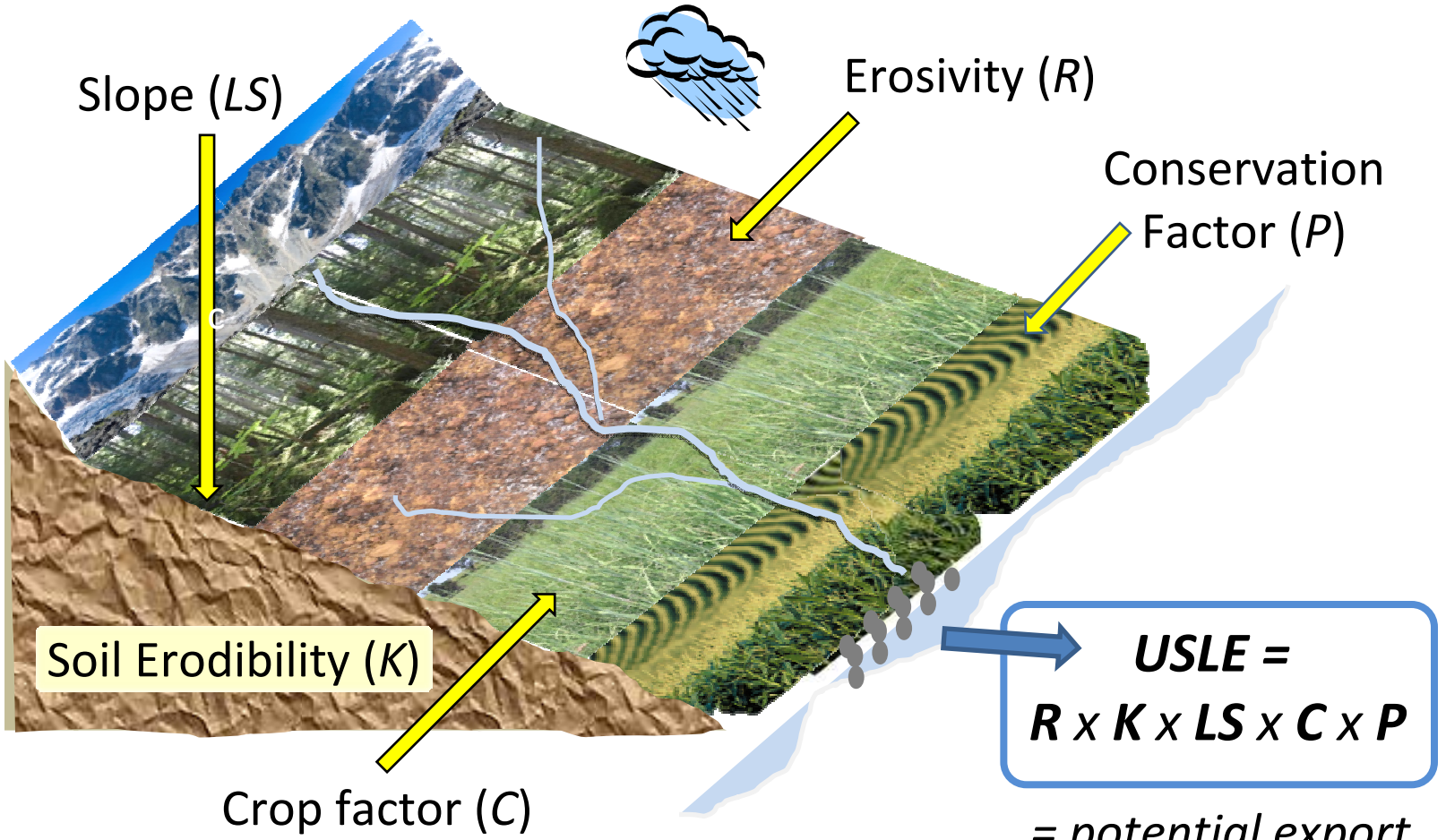
- Includes geomorphology and climate
- Nitrogen and phosphorus
- Potential export from a parcel



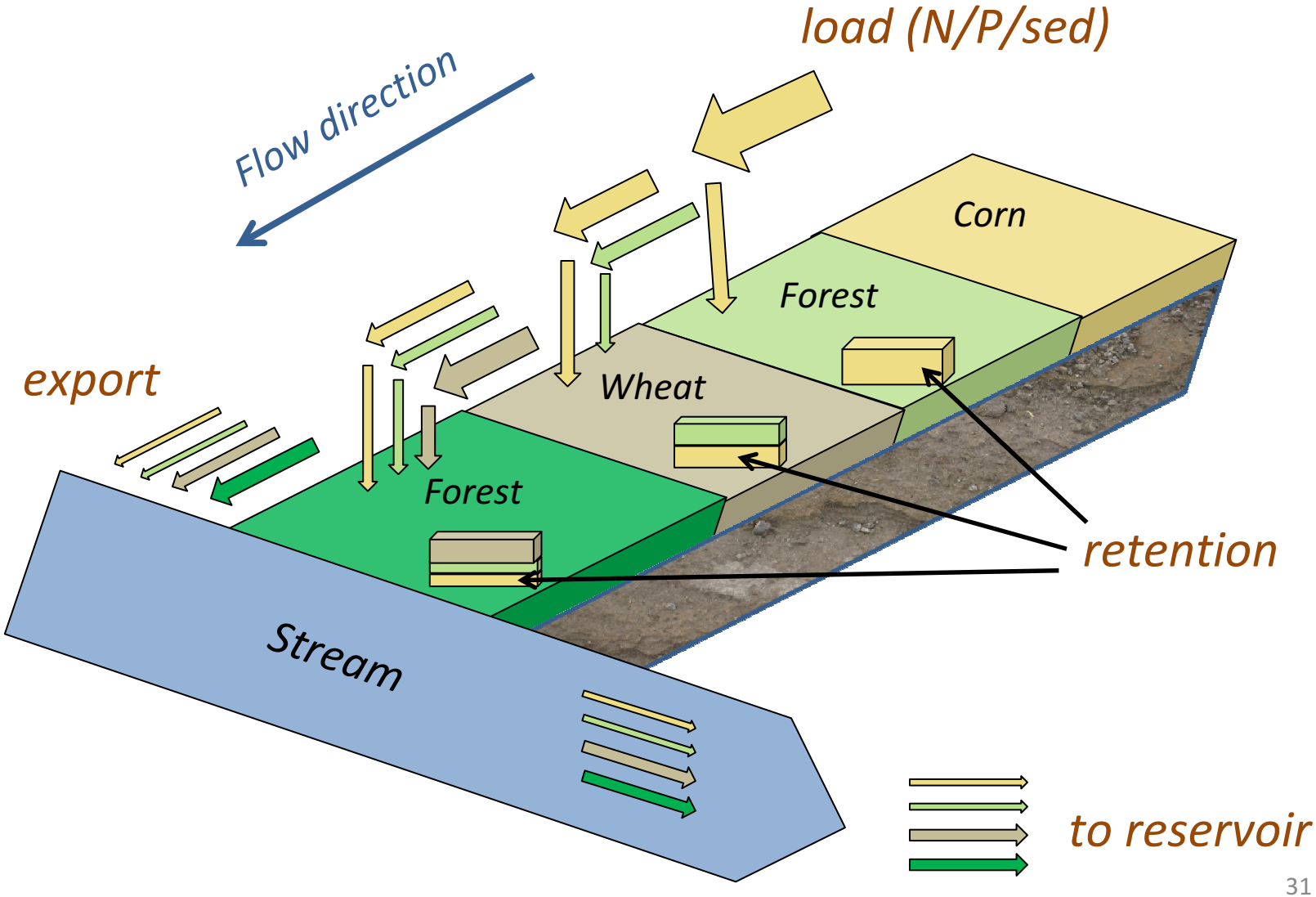
Landuse	Nitrogen Export Values (kg/ha/yr)	Phosphorus Export values (kg/ha/yr)
Forest	1.8	0.011
Corn	11.1	2
Cotton	10	4.3
Soybeans	12.5	4.6
Small Grain	5.3	1.5
Pasture	3.1	0.1
Feedlot or Dairy	2900	220
Idle	3.4	0.1
Residential	7.5	1.2
Business	13.8	3
Industrial	4.4	3.8

Sediment Retention Model

Based on the Universal Soil Loss Equation (USLE)

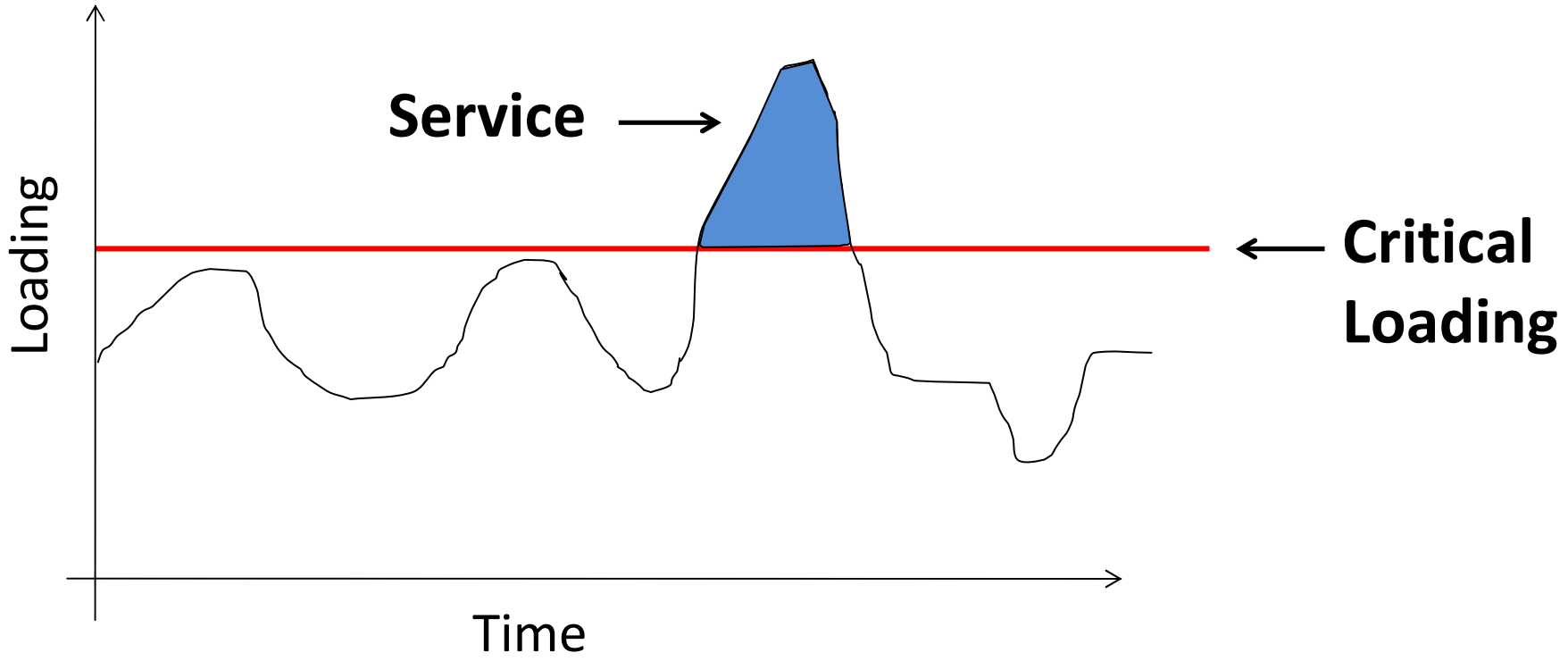


Hydrologic Connectivity



Valuation

Based on *avoided costs* (treatment or dredging)



Outputs - Nutrient

Nutrient Exported

Kg/year

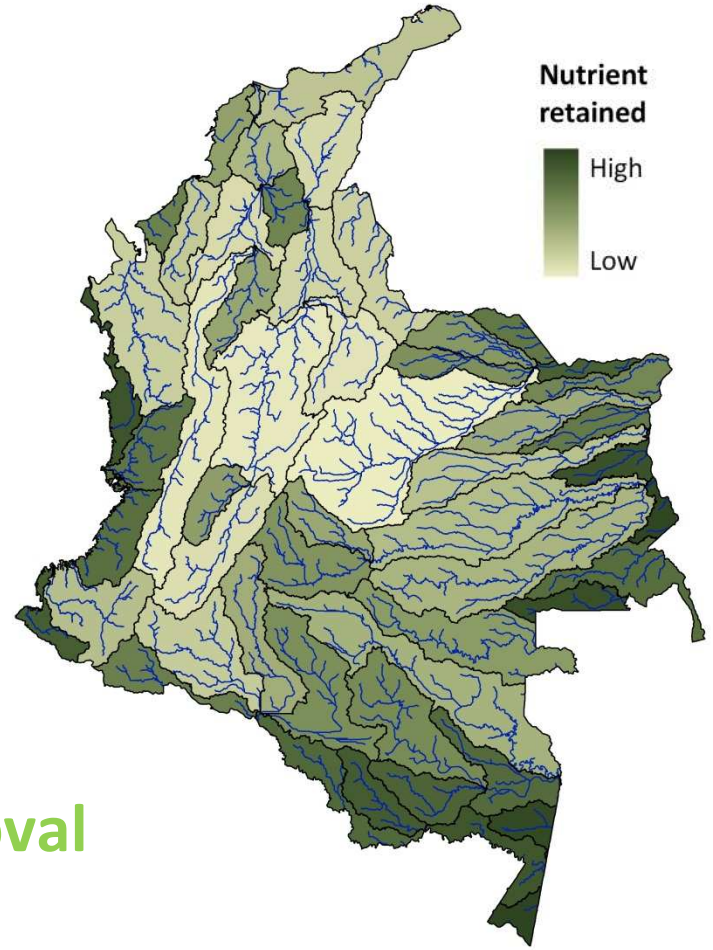
Nutrient Retained

Kg/year

Used in valuation

Value of Nutrient Removal for Water Quality

Currency over time period



Outputs - Sediment

Potential Soil loss

Calculated from USLE

Tons/year

Sediment Retained

Tons/year

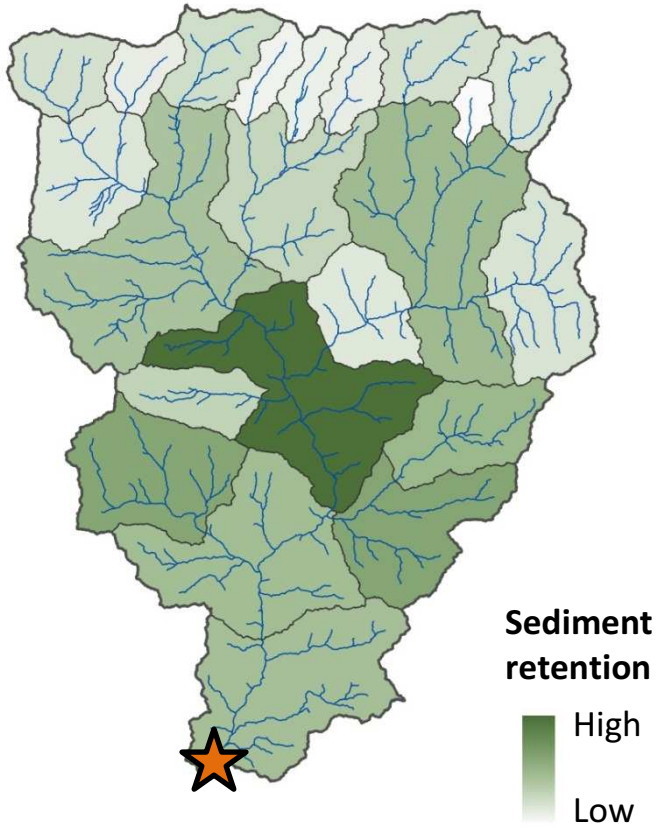
Used in valuation

Sediment Exported

Tons/year

Value of Sediment Removal for Water Quality/Dredging

Currency over time period



+ Total export to reservoir


InVEST
Biodiversity:
Habitat Quality
and Rarity

Habitat Quality: Model Overview

- Biodiversity is not treated as an ecosystem service per se
- Instead, it's used to assess overlaps and tradeoffs
- InVEST models habitat quality and rarity as indicators of the status of biodiversity
- Areas with high quality are generally better able to maintain biodiversity

Habitat Quality: Model Overview

Habitat quality depends on:

- Suitability of the habitat for the species of interest

  Does it prefer grassland, open canopy forest or closed canopy forest?

- Proximity and intensity of threats

  Proximity: *how far away is the threat?*

  Intensity: *how severe a threat is it?*

Habitat Quality: Threats

Degradation of habitat depends on:

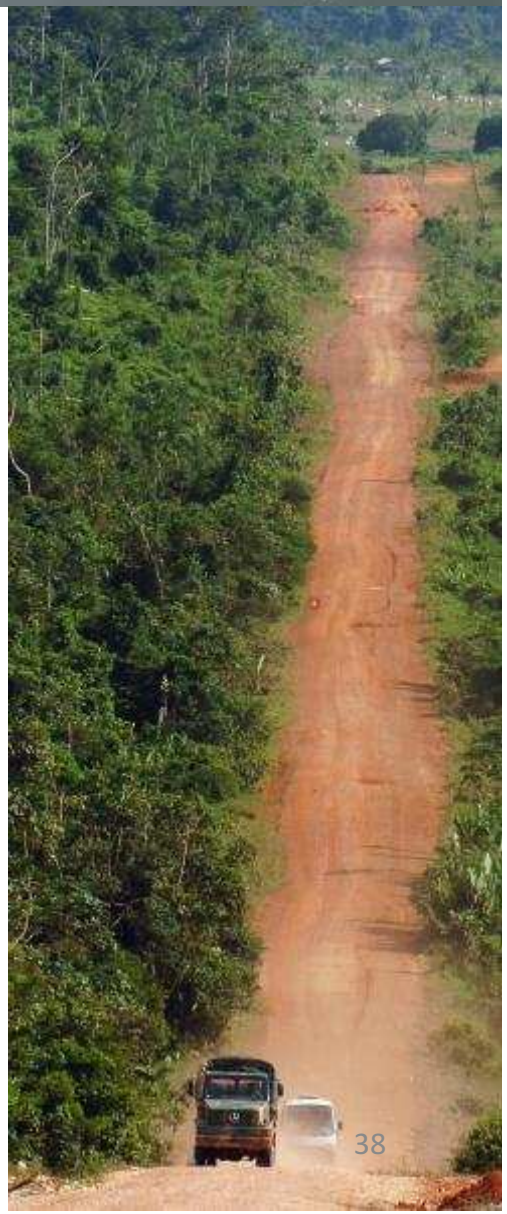
- Distance between habitat and threat
- Relative weight of threat

  Are highways a greater threat than dirt roads?

- Sensitivity of habitat to the threat

  Is forest more sensitive to roads than a grassland would be?

- How quickly the impact decays with distance
- Accessibility / Protection status



Data needs

REQUIRED

- Current LULC map
- Threat information table
- Threat maps
- Habitat information and sensitivity table
- Half-saturation constant value

OPTIONAL

- Future LULC map
- Baseline LULC map
- Accessibility and/or protected areas map

Model Outputs

- Habitat degradation

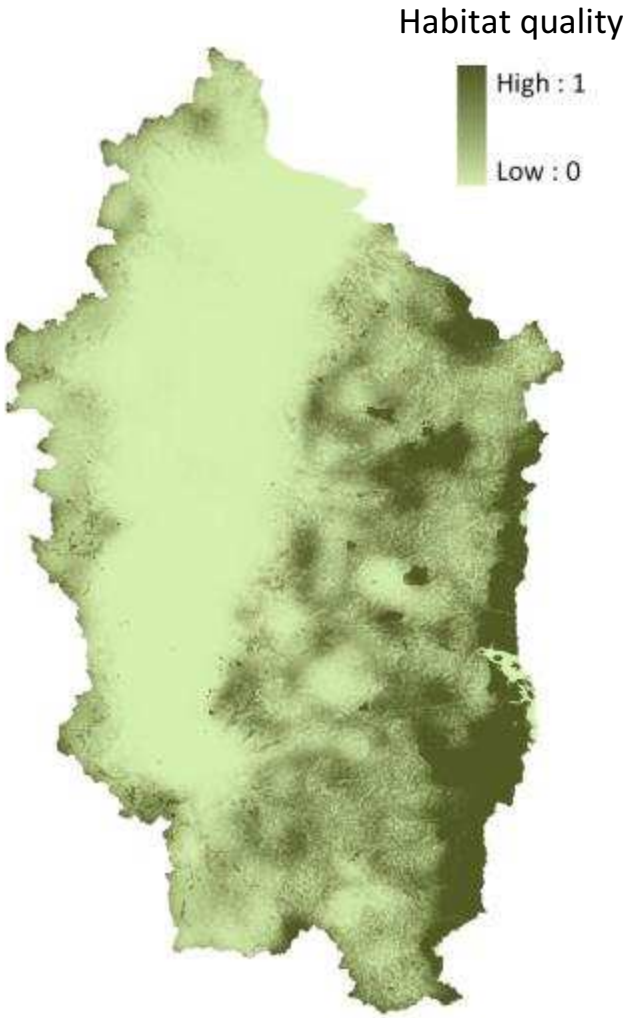
  relative to rest of landscape

- Habitat quality

  relative to rest of landscape

- Habitat rarity

  relative to baseline



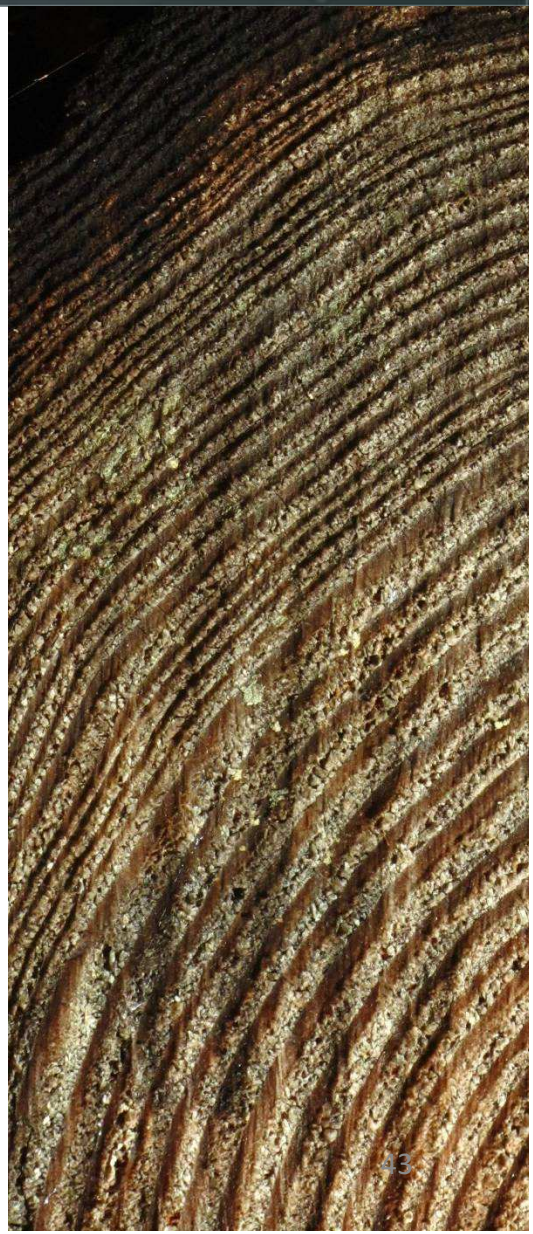
Ongoing Work: GLOBIO

- We implement GLOBIO's methodology with several improvements:
  - Can be used with high-resolution, local data
  - Assign LULC sub-classes with more precision
    - Based on high-res data rather than continent-wide aggregates
  - Improved fragmentation and infrastructure effects
  - The model quickly (1-click) calculates MSA for thousands of possible scenarios
    - Identify thresholds
  - Python script only (no interface)

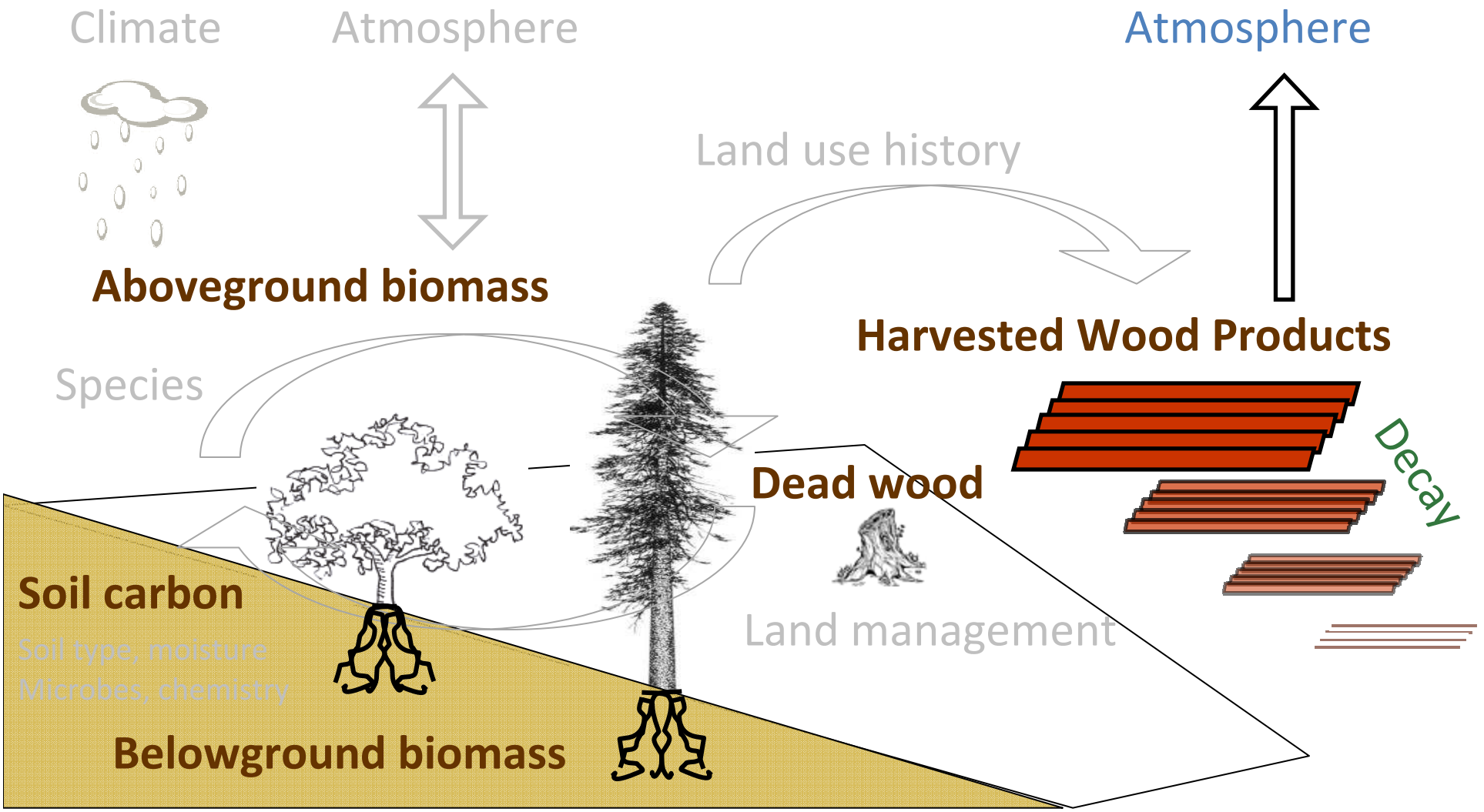

InVEST
Carbon Storage
and Sequestration
GREENPEACE

InVEST Carbon Storage Model

- Carbon stock as a function of land use/land cover
- Storage indicates the mass of carbon in an ecosystem at any given point in time.
- Sequestration indicates the change in carbon storage in an ecosystem over time.
- Valuation is applied to sequestration

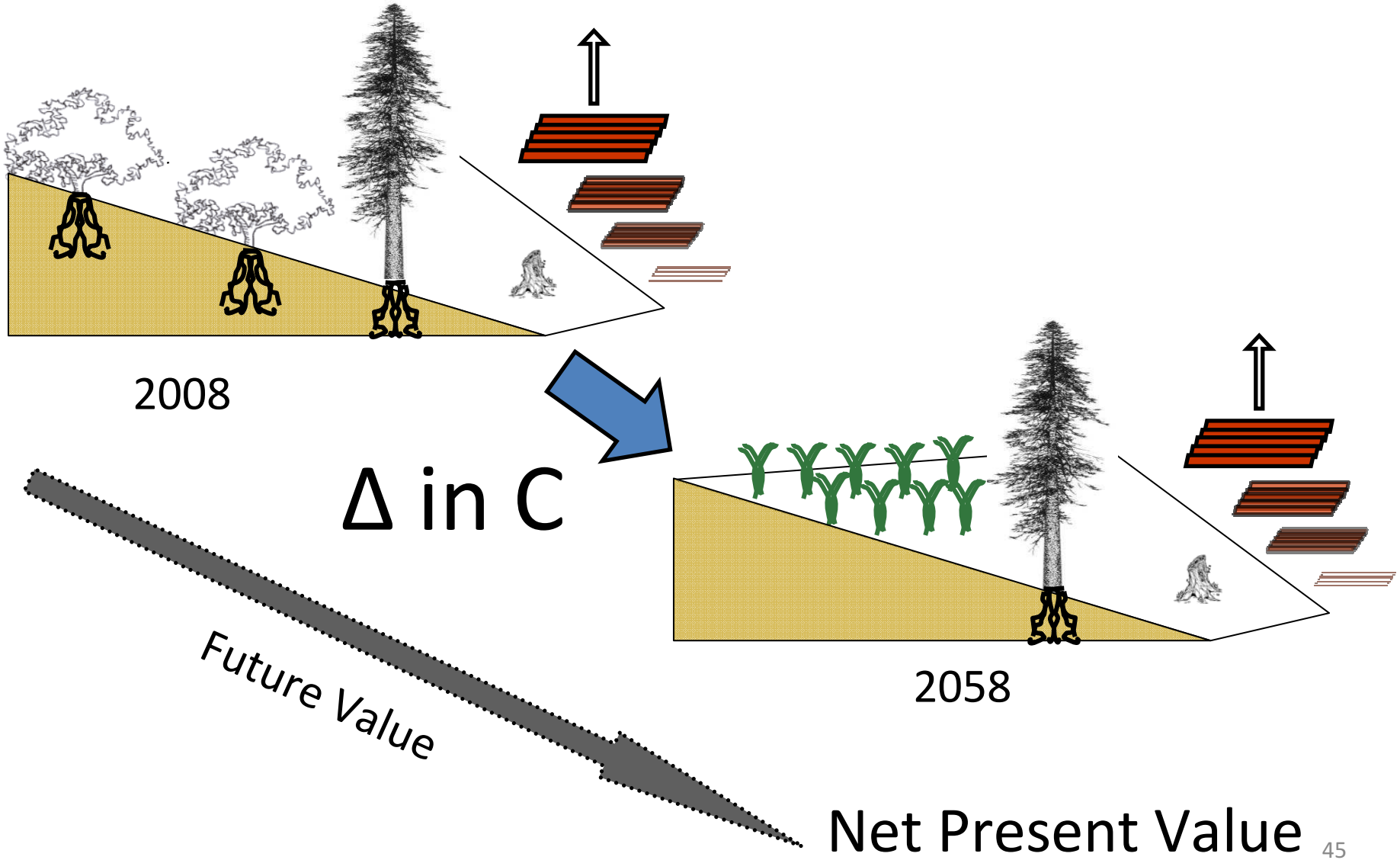


InVEST Carbon Storage Model



5 pools x *f*(cost/ton) = Value

Sequestration and Value



Input Data

Required data:

Land use / land cover (LULC) map

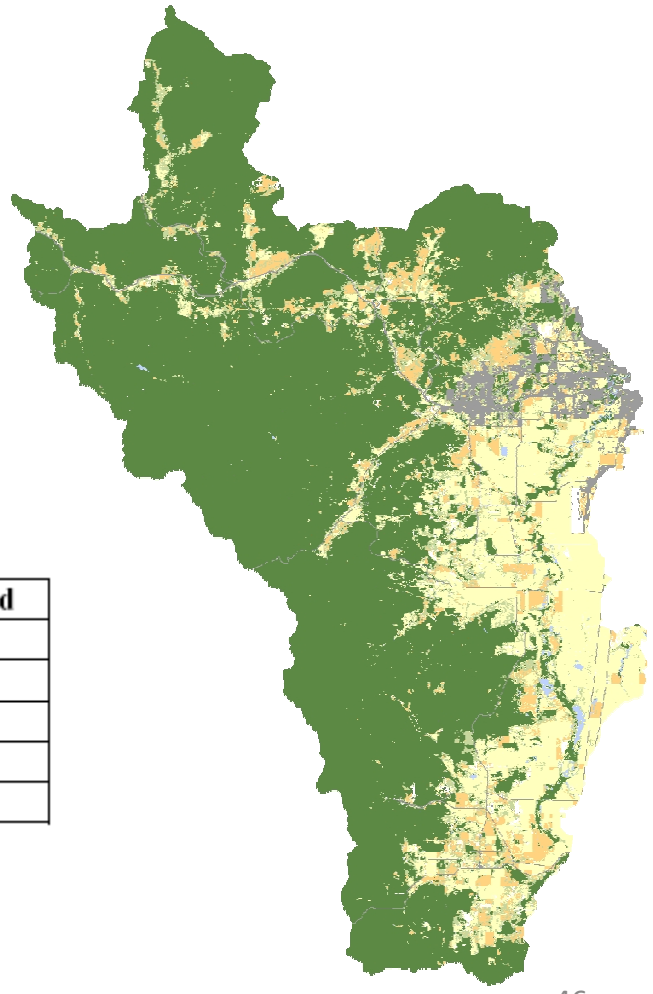


Table of carbon pools

(metric tons / hectare)

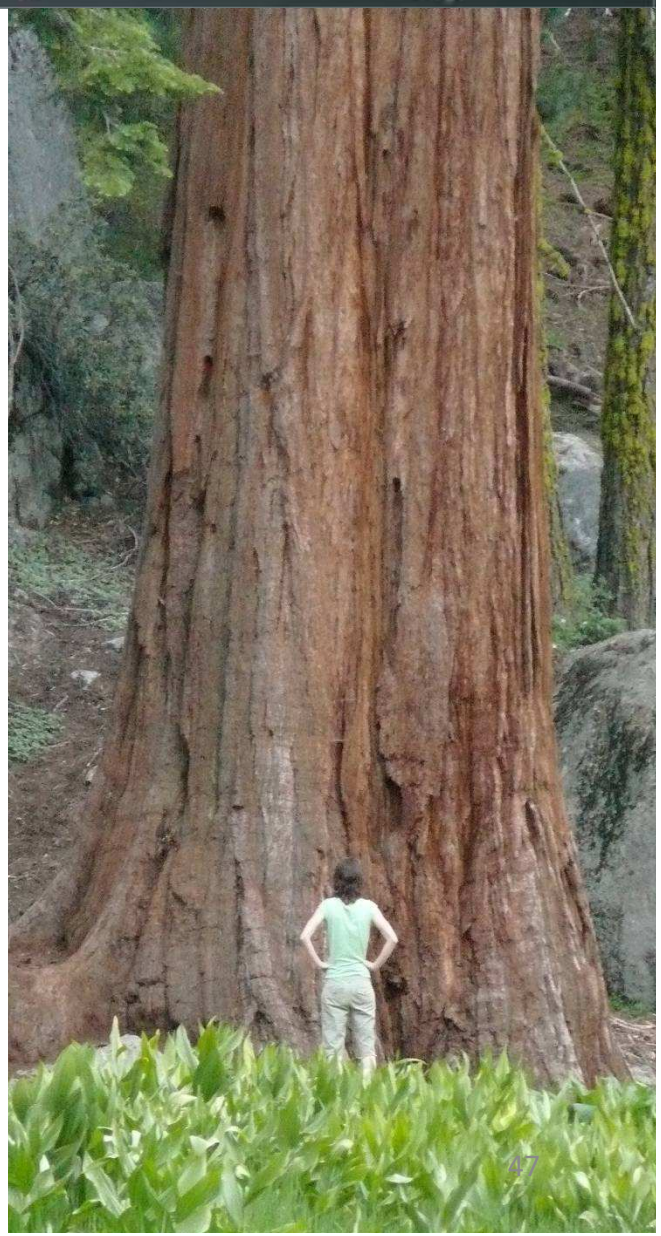
LULC	LULC_name	C_above	C_below	C_soil	C_dead
1	Forest	140	70	35	12
2	Coffee	65	40	25	6
3	Pasture/grass	15	35	30	4
4	Shrub/undergrowth	30	30	30	13
5	Open/urban	5	5	15	2

Approach to Valuation

Net Present Value is a function of:

- Market discount rate
- Rate of change in the social value of carbon
- Social or market cost of carbon

Carbon model is most appropriate for valuing the **Social cost of carbon:** What is the benefit to society from avoiding damage from CO_2 release?



Output

- Map of current carbon storage (Mg C / cell)
- Map of future carbon storage
  - If future land use provided
- Carbon sequestration map
  = (future - present storage)
- Map of economic value of carbon sequestered

Thank You!

Adrian Vogl

Program Manager, Freshwater Services

Natural Capital Project, Stanford University

avogl@stanford.edu

Application

How much impact will a proposed infrastructure project have on ecosystem services?

Who will lose which services?

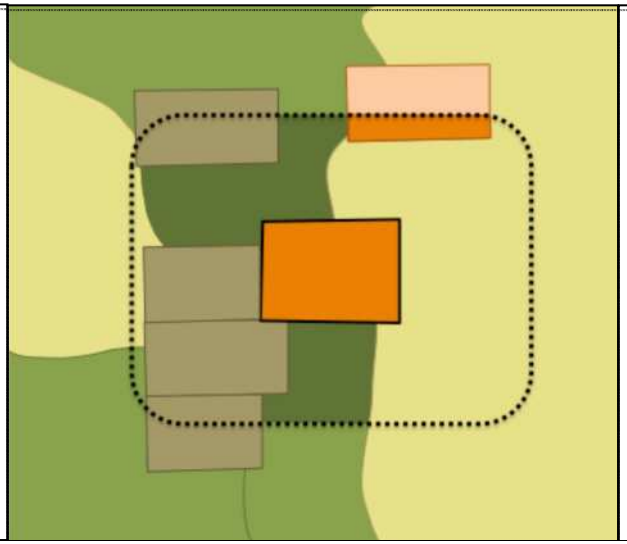
Servicesheds

Serviceshed: area that provides a specific benefit to a specific group of people

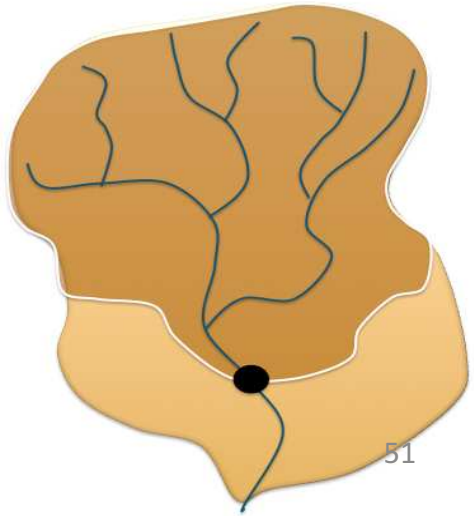
- Supply
- Physical access
- Institutional access

C A R B O N

P O L L I N A T I O N



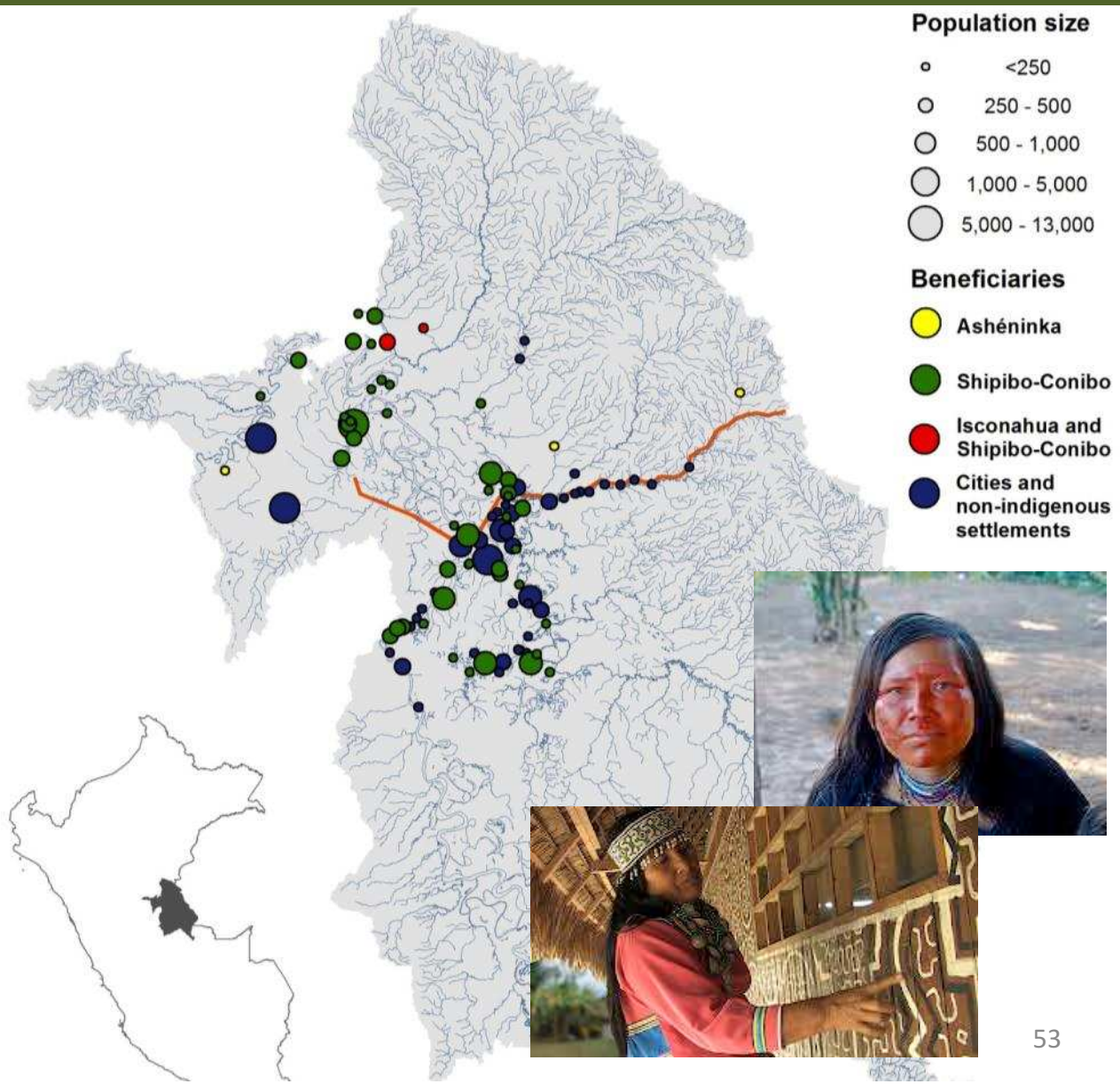
W A T E R



Proposed Road

Lisa Mandle, Jerry Touval, Leandro Baumgarten, et al.

Beneficiaries



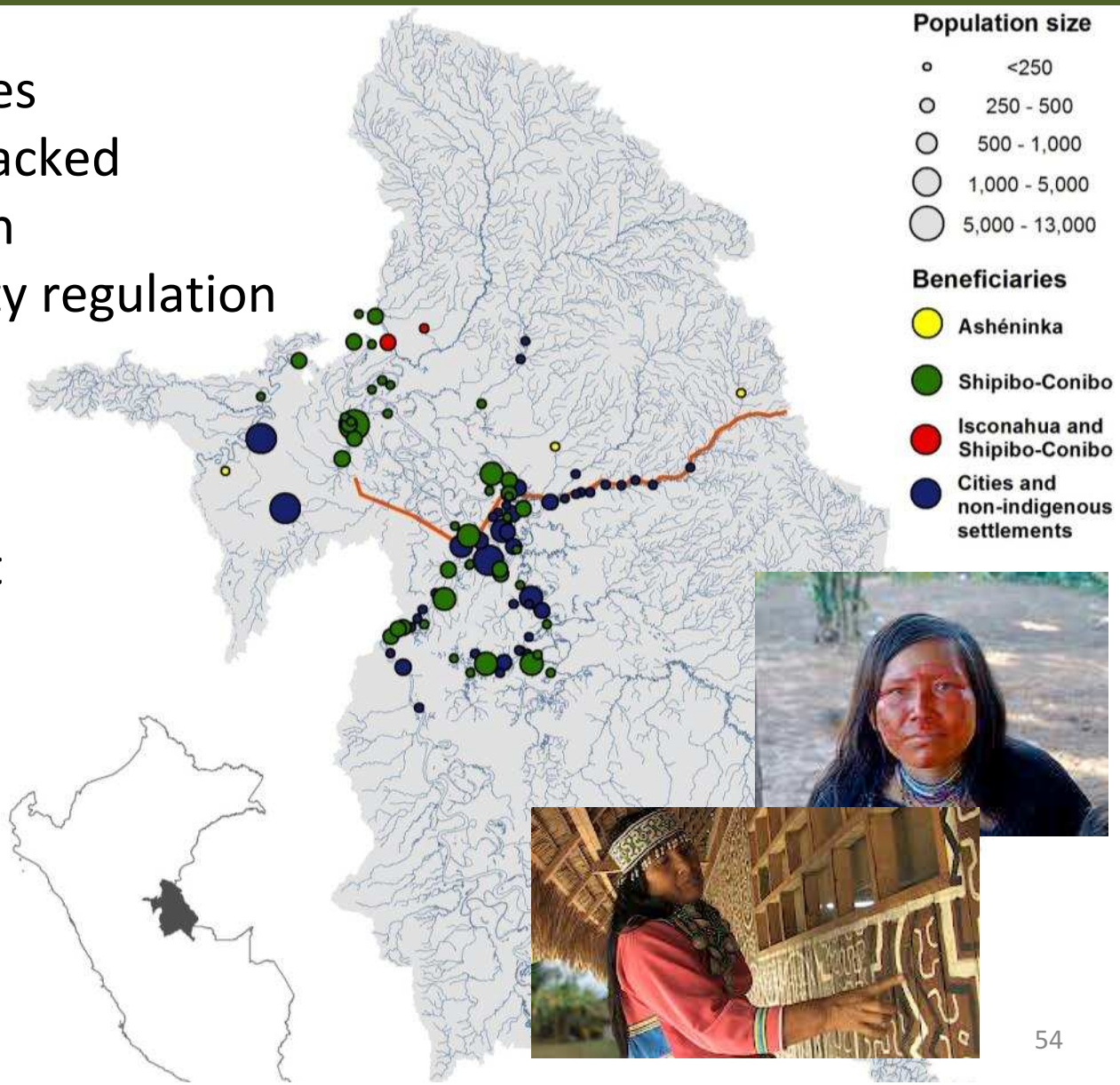
Services

Towns as beneficiaries
- -ethnic groups tracked

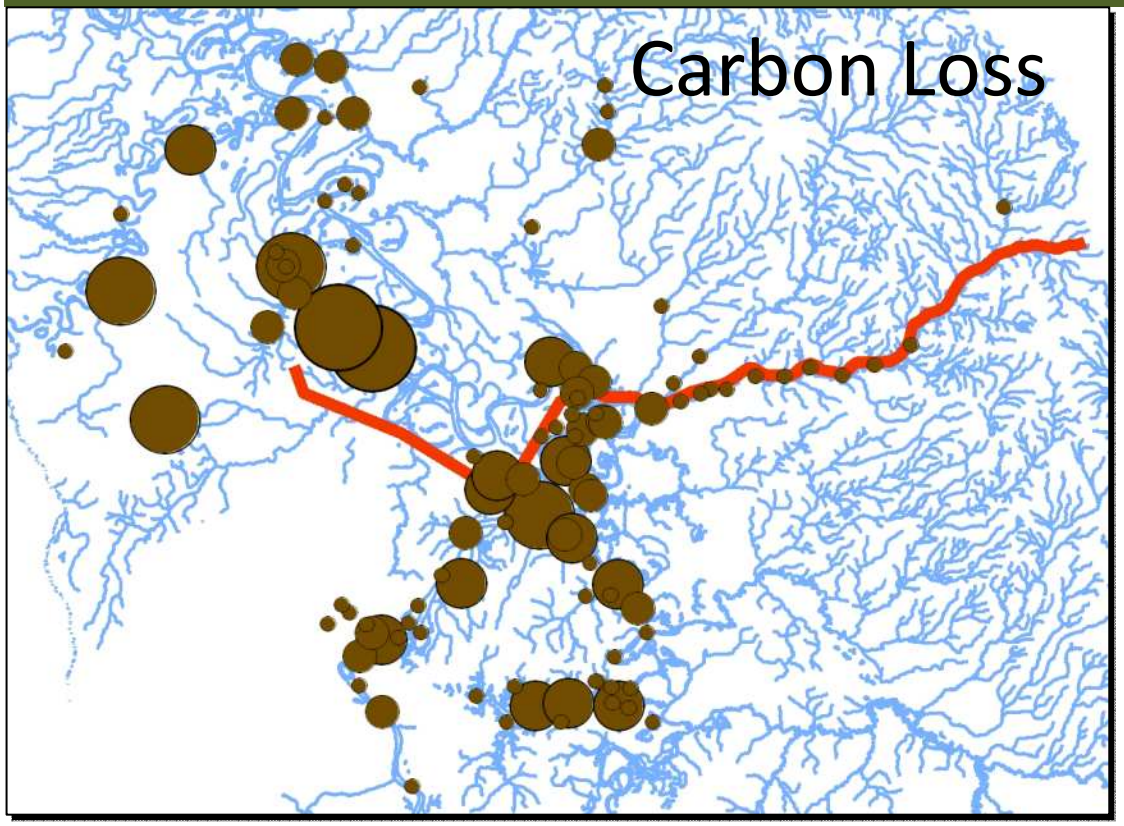
Carbon sequestration

Drinking water quality regulation
- Nitrogen
- Phosphorus
- Sediment

Wild product harvest



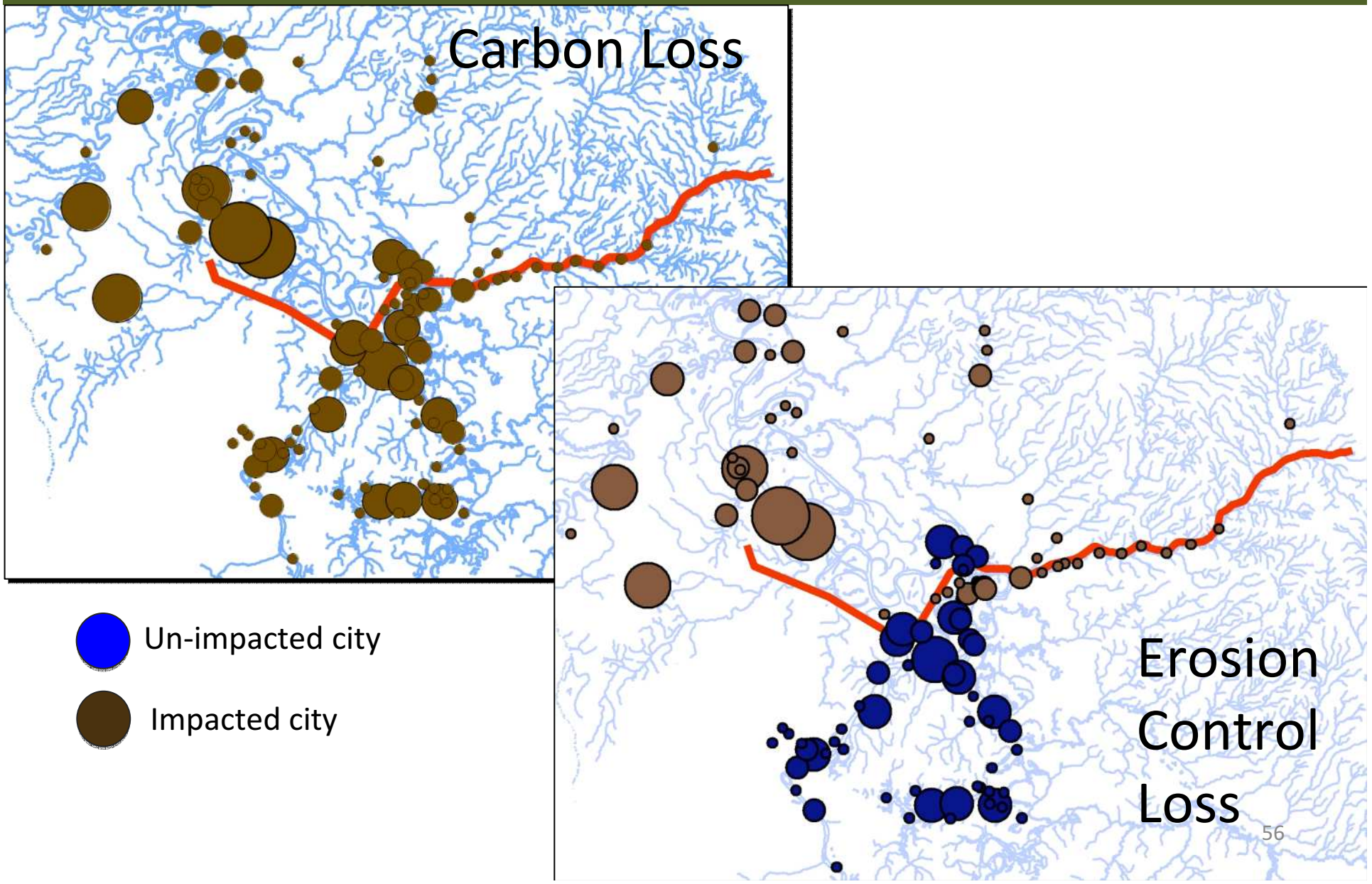
Who Will Lose Which Services?



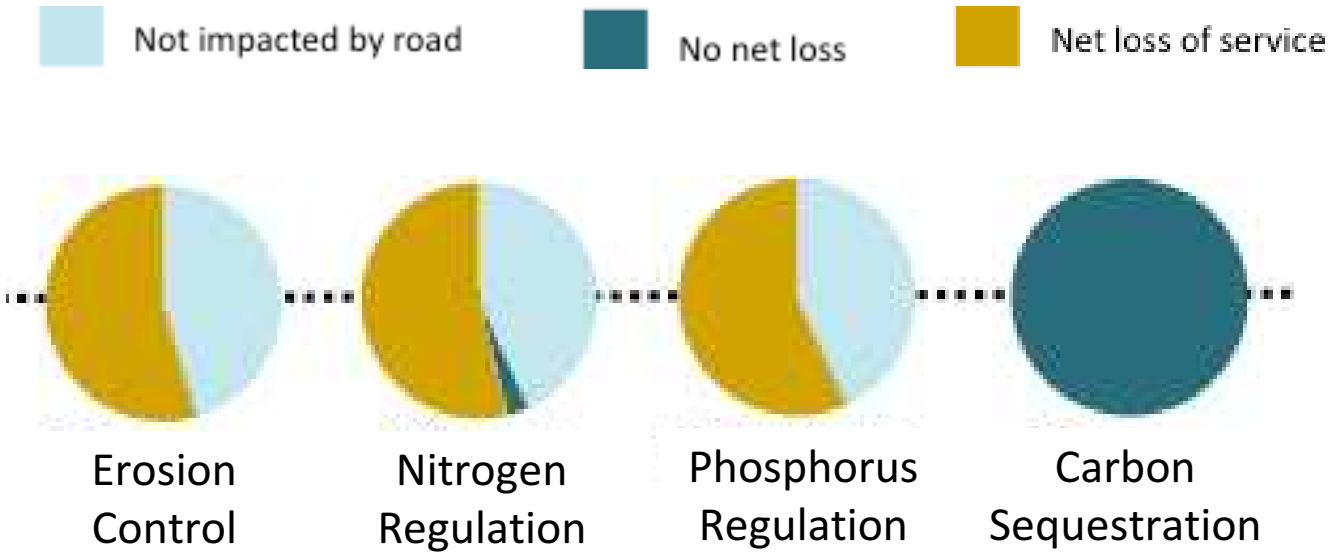
Un-impacted city

Impacted city

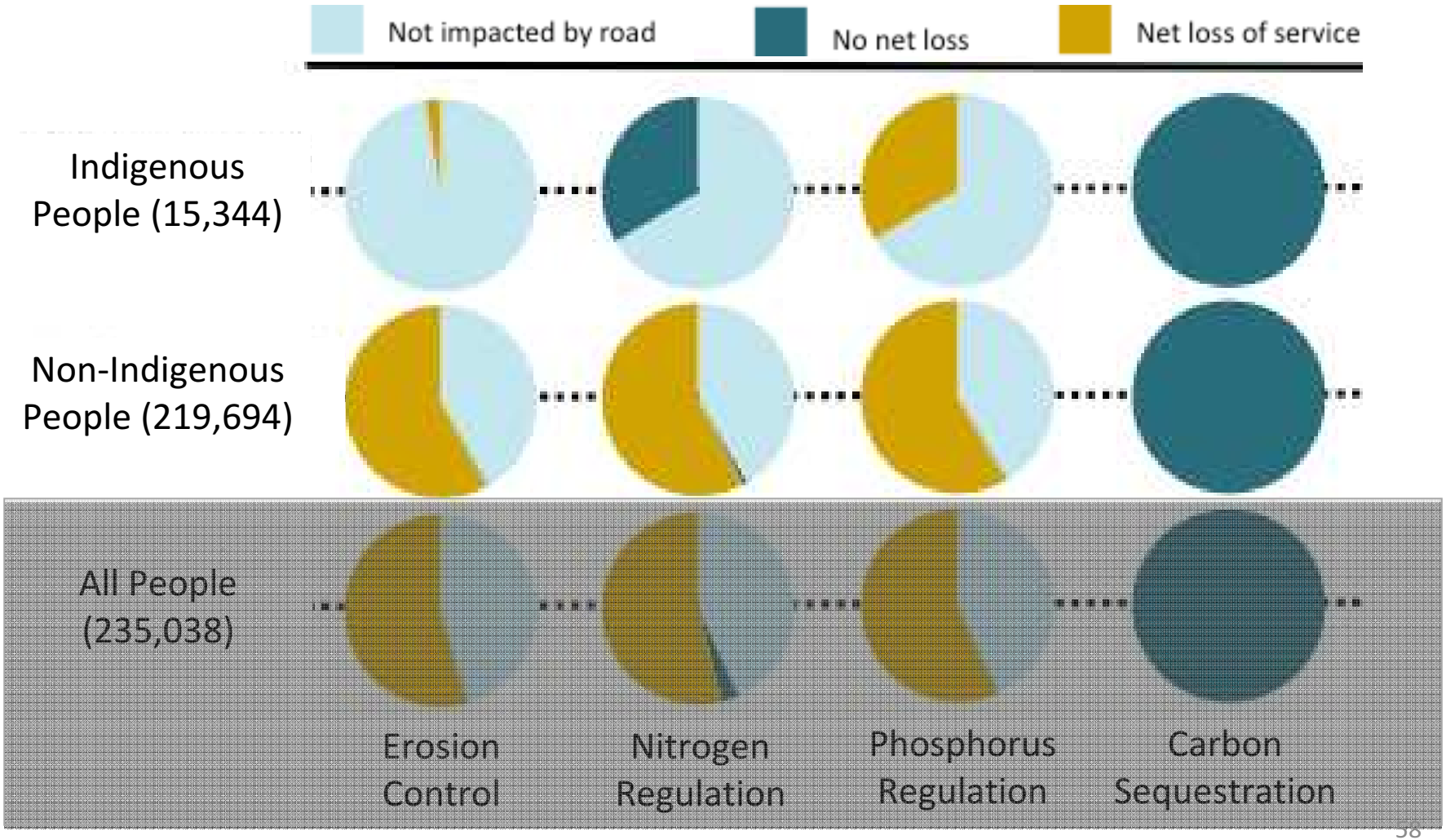
Who Will Lose Which Services?



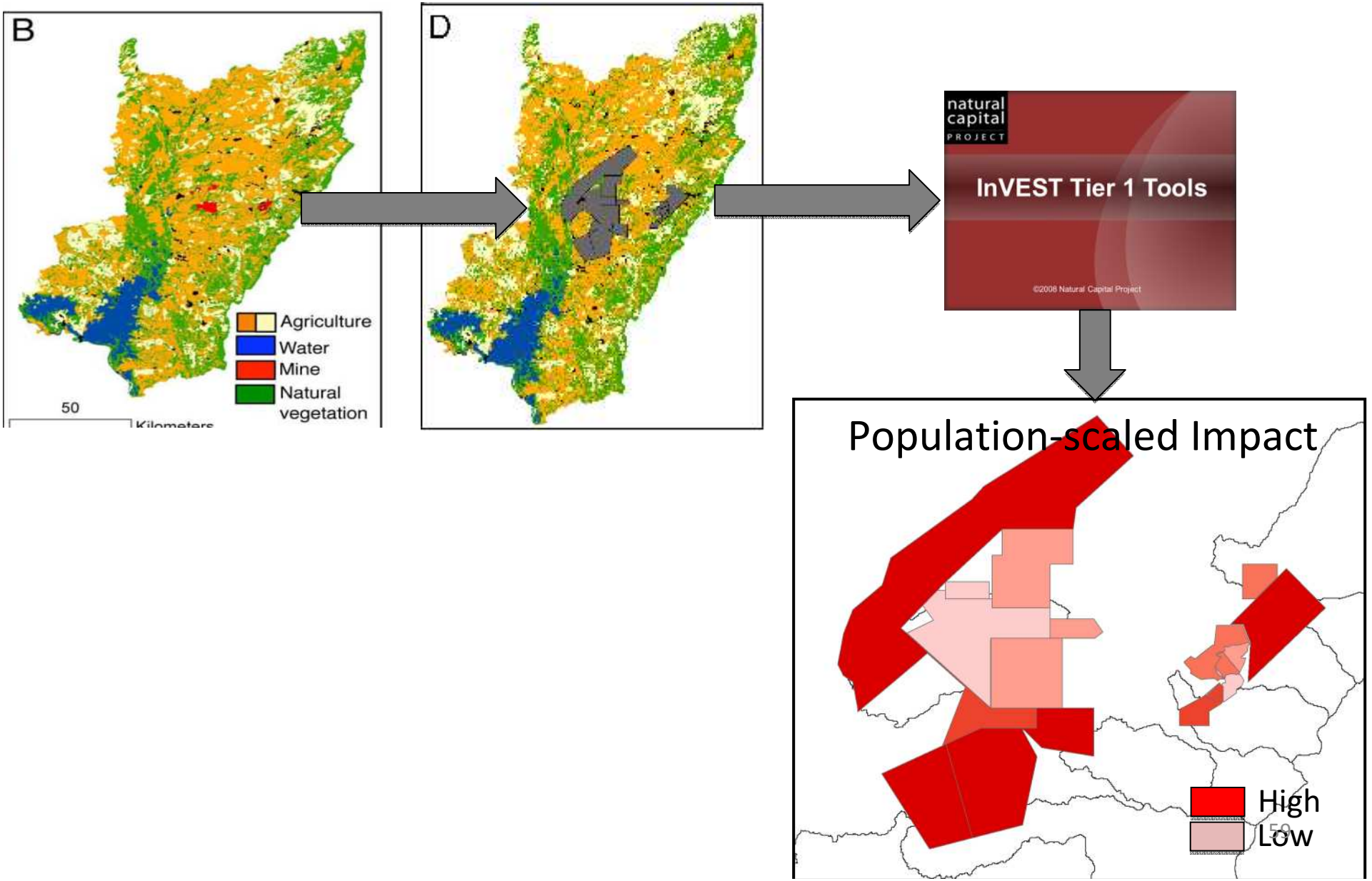
Who Loses After Mitigation?



Who Loses After Mitigation?



Which Permits Have the Most Impact?

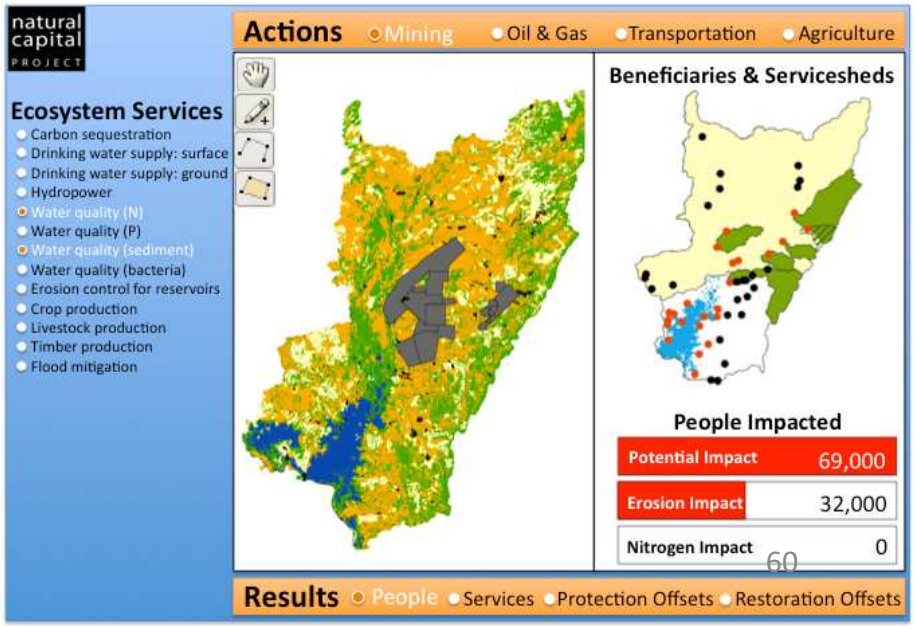


Ongoing Work

- Application in Indonesia with Millennium Challenge Corporation and Rockefeller Foundation

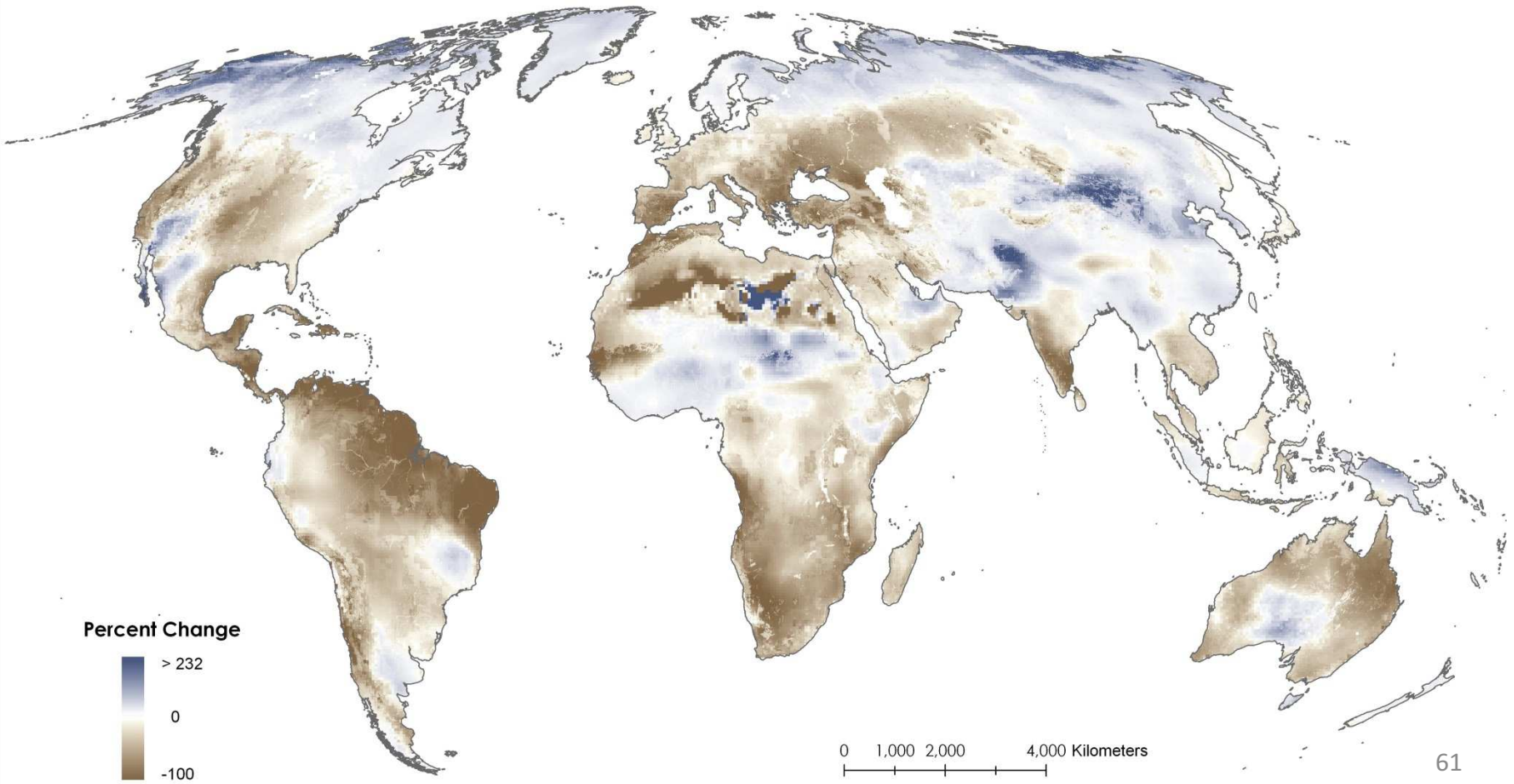
- Application with Colombian Ministry of Environment, simple online tool for all sectors

- Aligning with biodiversity approach



Application

Predicted water yield change 1990-2060, HADCM climate change model



Application

Predicted per capita water yield change 1990-2060, HADCM climate change model