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Ecosystem Services Assessment at Watershed Scale using InVEST

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WWF

The Nature Conservancy

Institute on the Environment University of Minnesota Driven to Discover

The Natural Capital Project

Incorporating ecosystem services in decisions

Spatial Planning

Payment for Ecosystem Services (PES)

Climate Adaptation Planning

Development Impacts and Permitting

Restoration Planning

Corporate Risk Management

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Ruckelshaus et al. in review

0 5,000 10,000 Kilometers

InVEST – Integrated Valuation of Ecosystem Services and Tradeoffs

- Ecosystem services are the goods and benefits society derives from ecosystems
- Examples: Water, Food, Energy (biomass), Pollination, Biodiversity
- Most ecosystem services cannot be directly measured, or are insufficiently monitored or reported
- The InVEST toolset is a science-based free open-source GIS software for modeling and mapping ecosystem services

InVEST Principles

- Developed for users considering holistic integrated multiple ecosystem services
- Land-use/land-cover based GIS models
- Incorporate models of the biophysical function (supply), the beneficiaries utilization (service) and optionally economic valuation
- Depending on data and resources availability, can be applied at different levels, for anything from screening to planning to compliance (albeit limited)

InVEST Models for Watersheds

- Nutrient Retention
- Habitat Quality
- Annual Water Yield
- Sediment Retention
- Habitat Risk Assessment
- *Monthly Water Yield*
- *Flood Mitigation*
- *Recreation*
- *Aesthetic Value*
- More InVEST models exists, as well as a suite of marine/coastal models. Check our website for full list www.naturalcapitalproject.org

Nutrient Retention

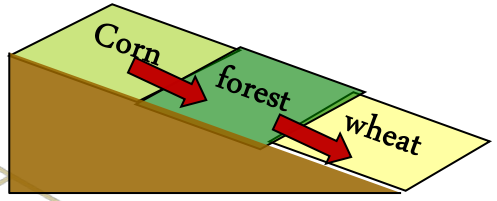
- Mainly aimed to assess reduction of N and P loading into freshwater by riparian buffers
- Inputs are loading and retention per LULC class
- The service performed by riparian vegetation is retaining N and P applied upstream (demand), decreasing treatment cost for downstream users (value)

1. Estimate Water yield

2. Calculate flow direction

3. Estimate Pollutant Load value

$$ALV_x = LV_x * A_x$$



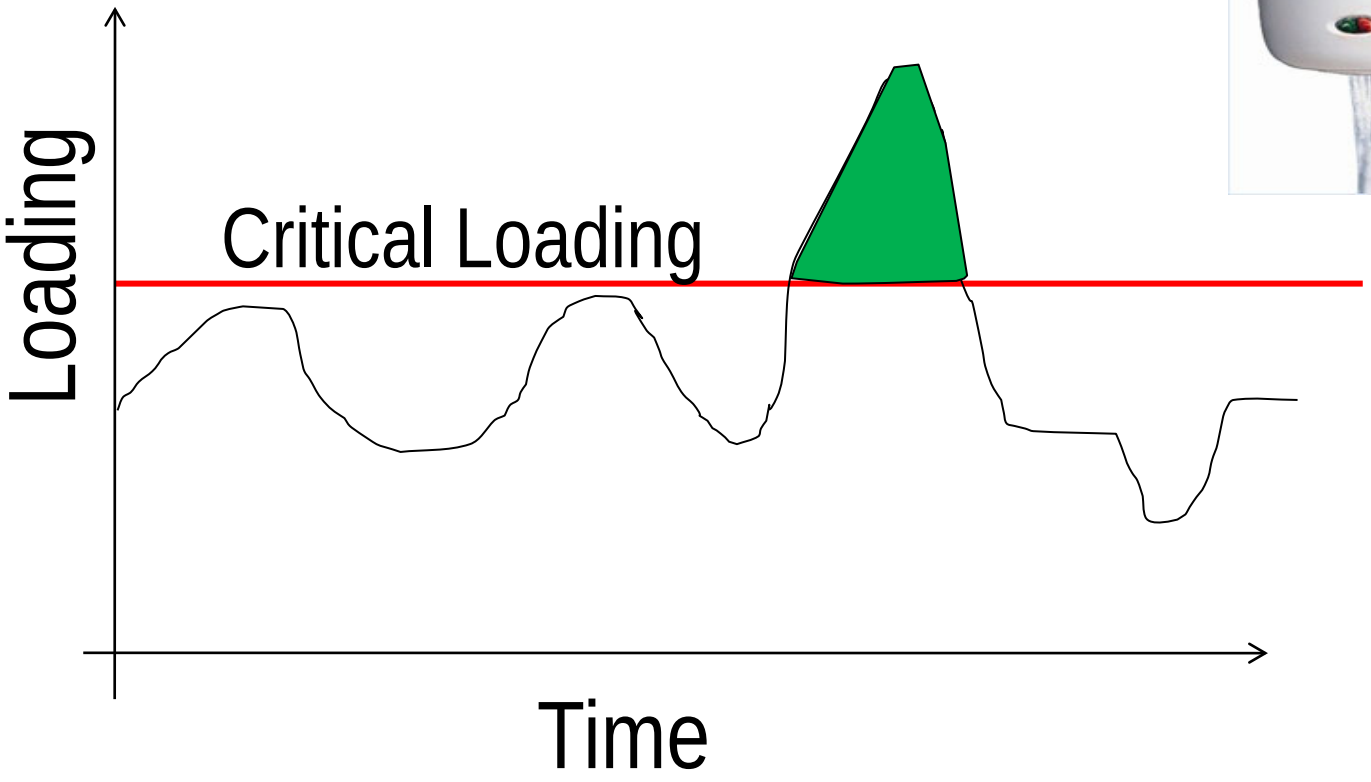
4. Estimate nutrient retained

$$Ret_x = ALV_x * R_x$$

5. Estimate pollutant reached the stream

Valuation

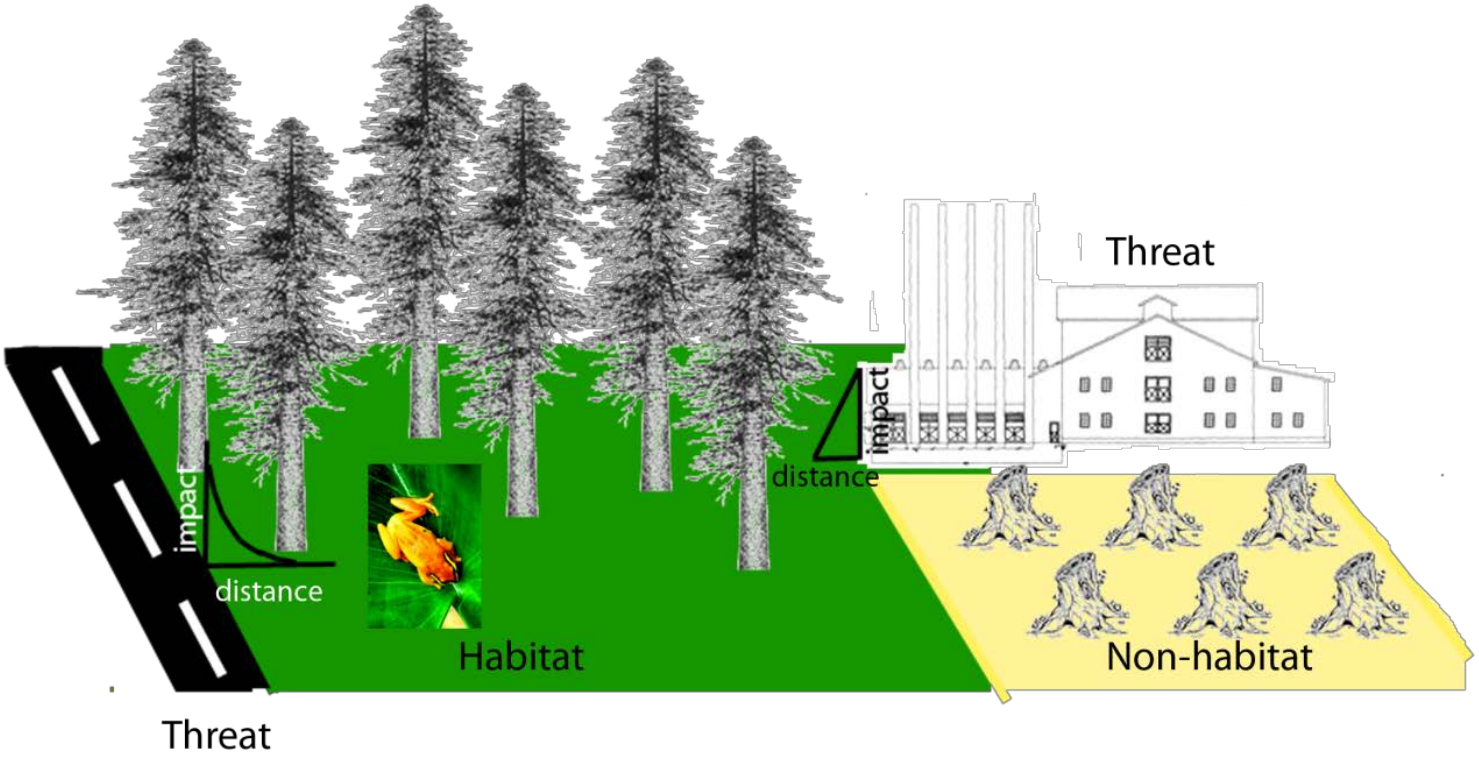
6. Estimate Avoided treatment costs



Habitat Quality

- Managing the quality of habitat allows for us to manage the associated species
- Produces a map of habitat quality
- Habitat is a function of conservation objective
  - Are we considering all species or just specific species? All animals on the landscape or just threatened ones?
- Threats to habitat can be divided into two major categories
  - Actual removal of habitat or edge fragmentation
  - Sources of pollution (e.g., noise), roads, power lines, etc. that degrade the integrity of habitat

Model Overview

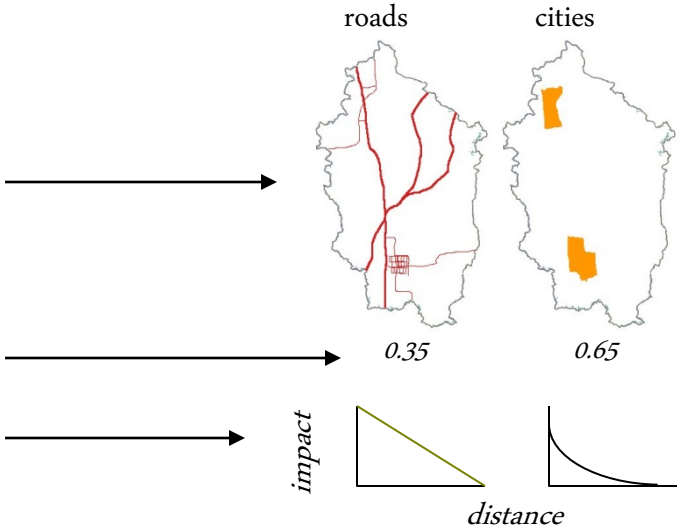


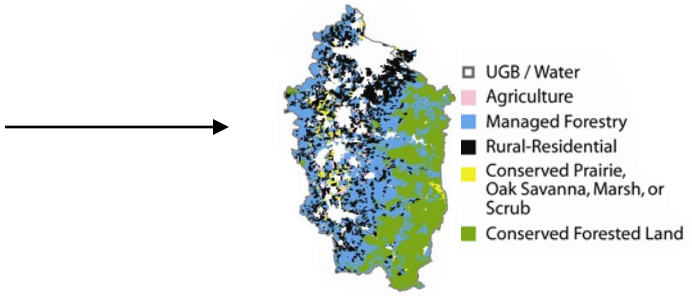
Alternative Models

- Heuristic models – (weighted overlay, crayon and paper approach)
  - Expert knowledge
  - Not statistical
- Statistical models – (MaxEnt, logistic regression, CART, ANN)
  - Often data intensive
  - Output is probability of occurrence or conversion
- Why the InVEST model?
  - Requires basic data that is widely available
  - Habitat approach can encompass multiple species
  - Compare scenarios to a baseline
  - Incorporate the spatial impacts of threats

Model Inputs

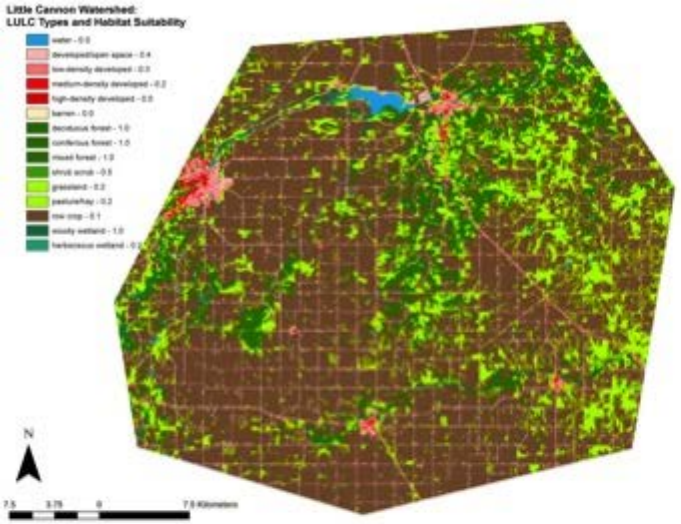
- Inputs
  - Map of each threat
  - Relative weights of threats (0.0 to 1.0)
  - Spatial impact of threats
  - Land use/land cover
    - habitat/nonhabitat
    - sensitivity of each habitat type to each threat
    - accessibility of habitat to threat (social, political, geographical restrictions)

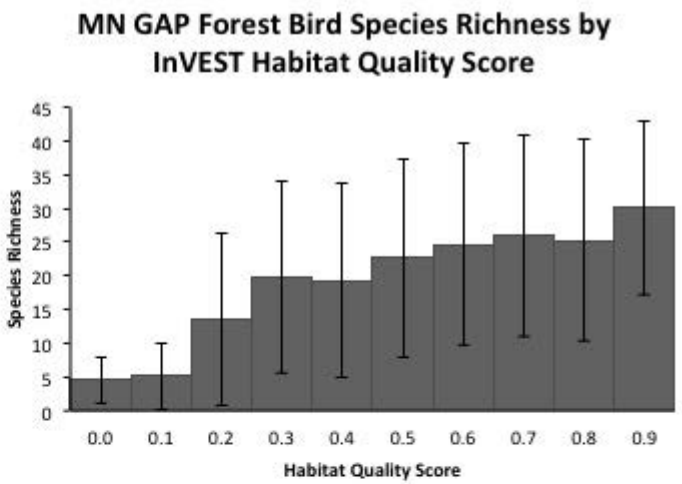


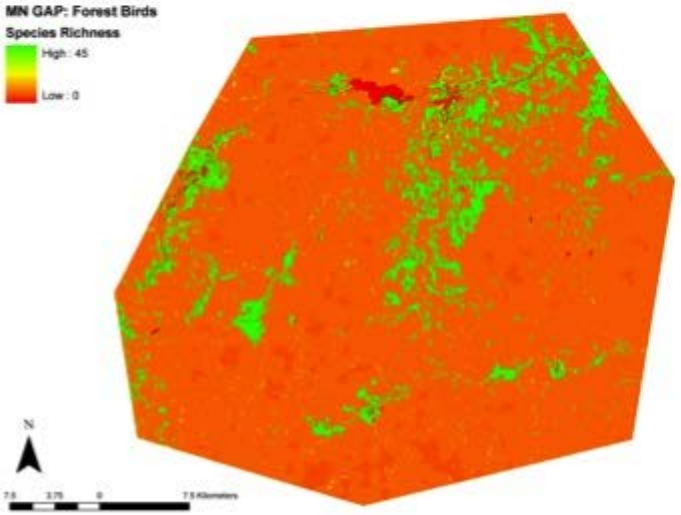


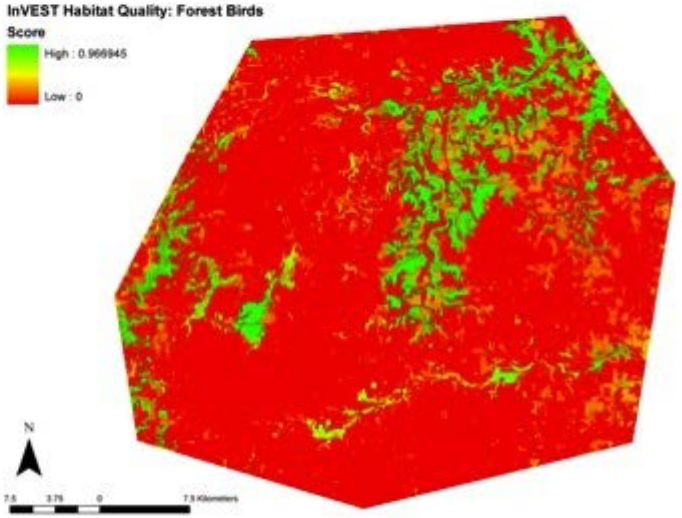
LULC

Validation of InVEST to GAP

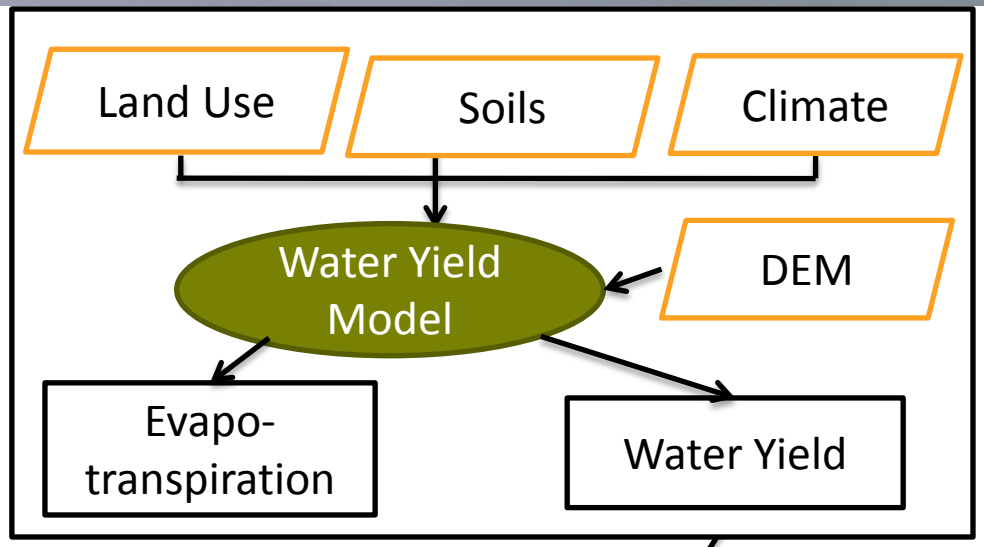


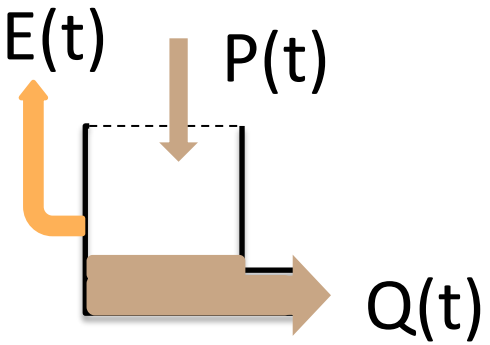


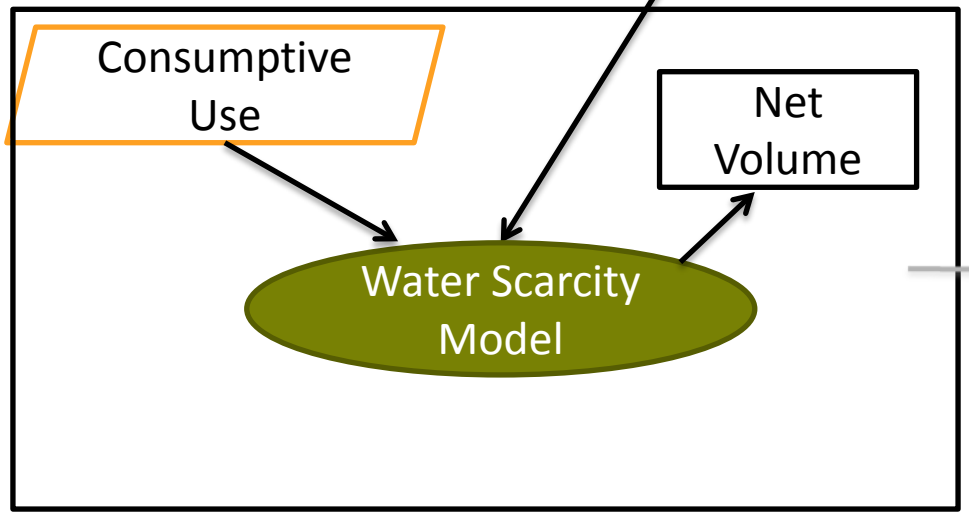


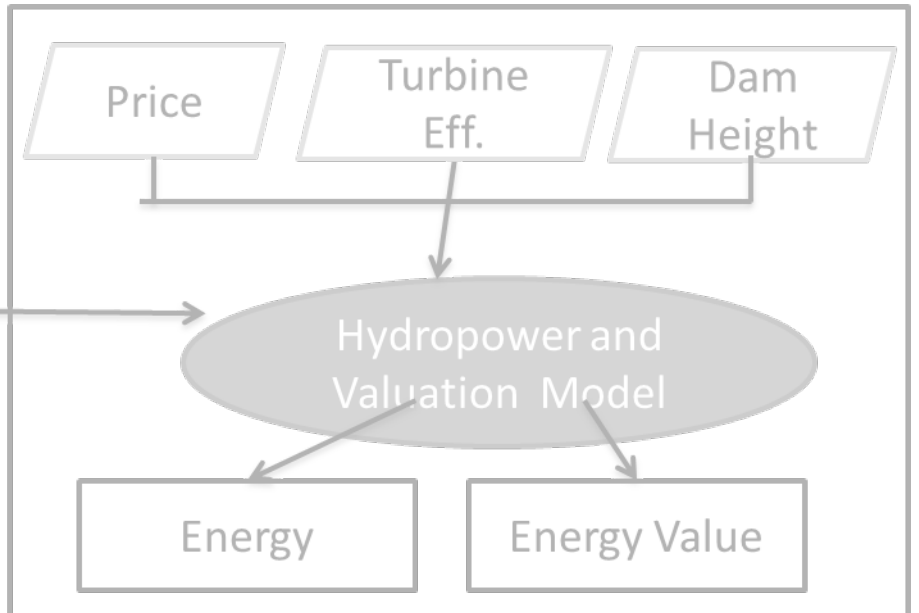


Annual Water Yield



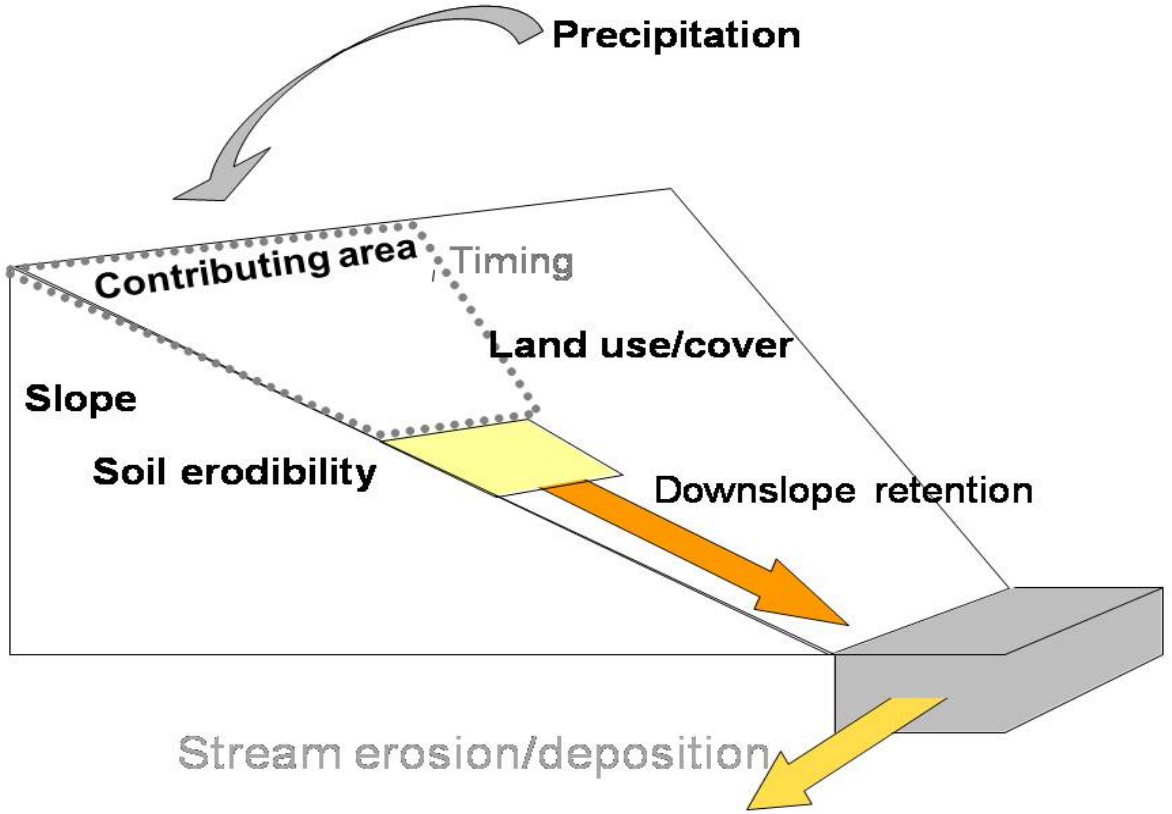






Sediment Retention

- Quantify sediment exported and retained on a landscape
- Uses USLE (with some RUSLE modifications) to estimate water erosion
- Valuation – avoided dredging cost, avoided water treatment



Targeting investments: which activities?

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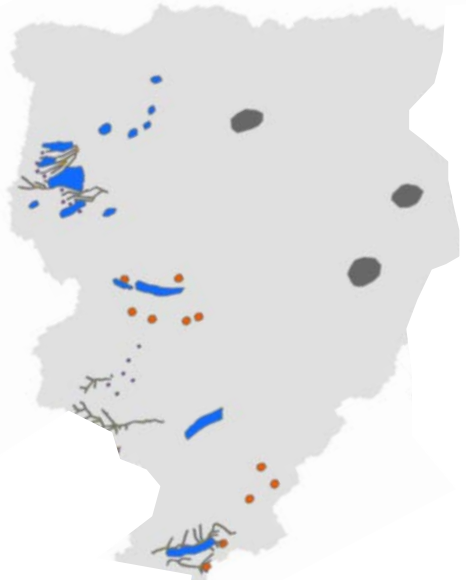
Biophysical Weights

Annual Water Supply

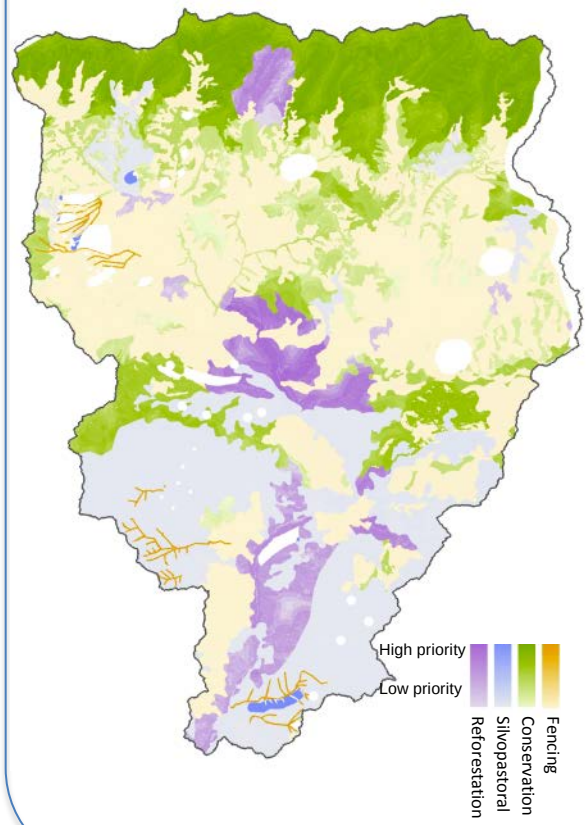
Erosion Control

Biodiversity

Stakeholder Preferences



Activity Rankings



Targeting investments: where to invest?

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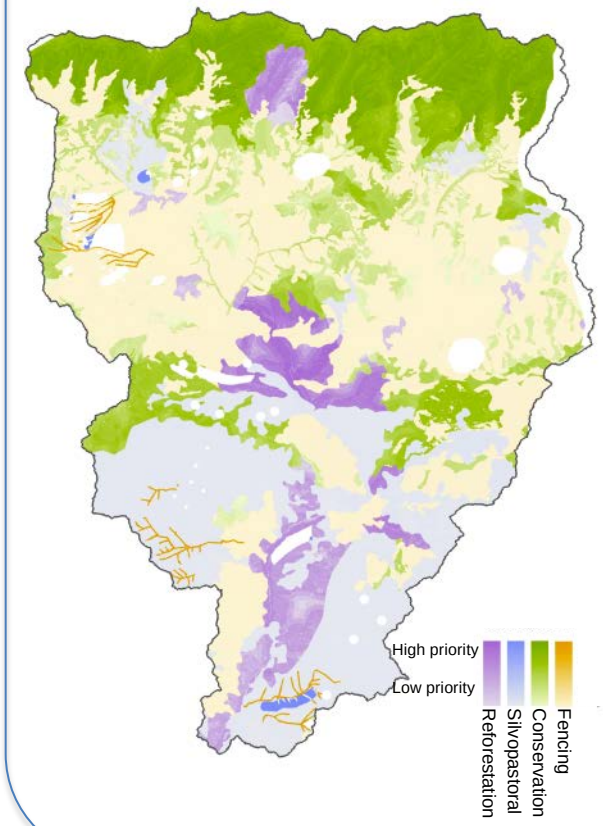
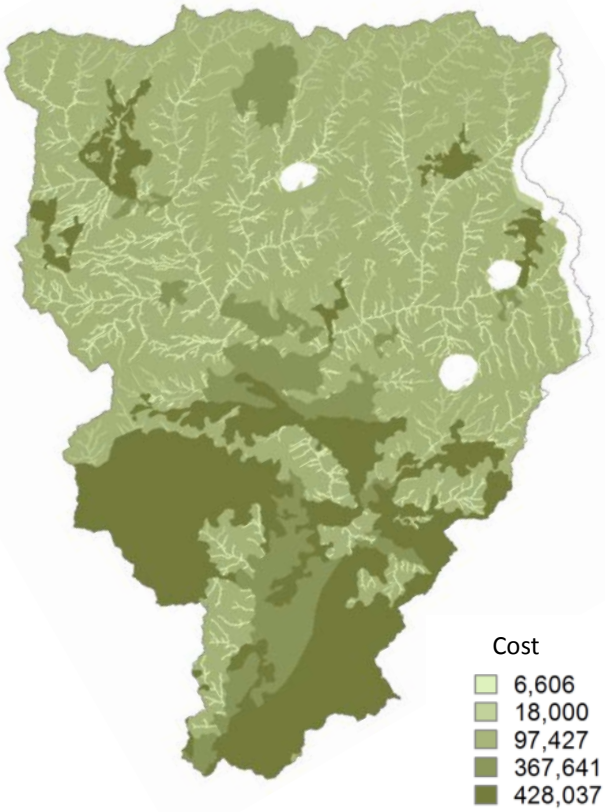
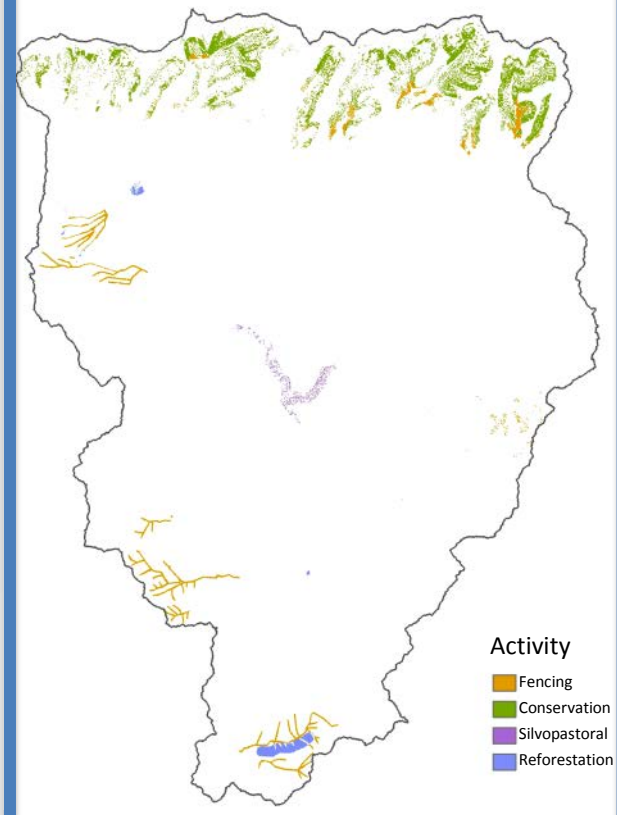
Activity Rankings



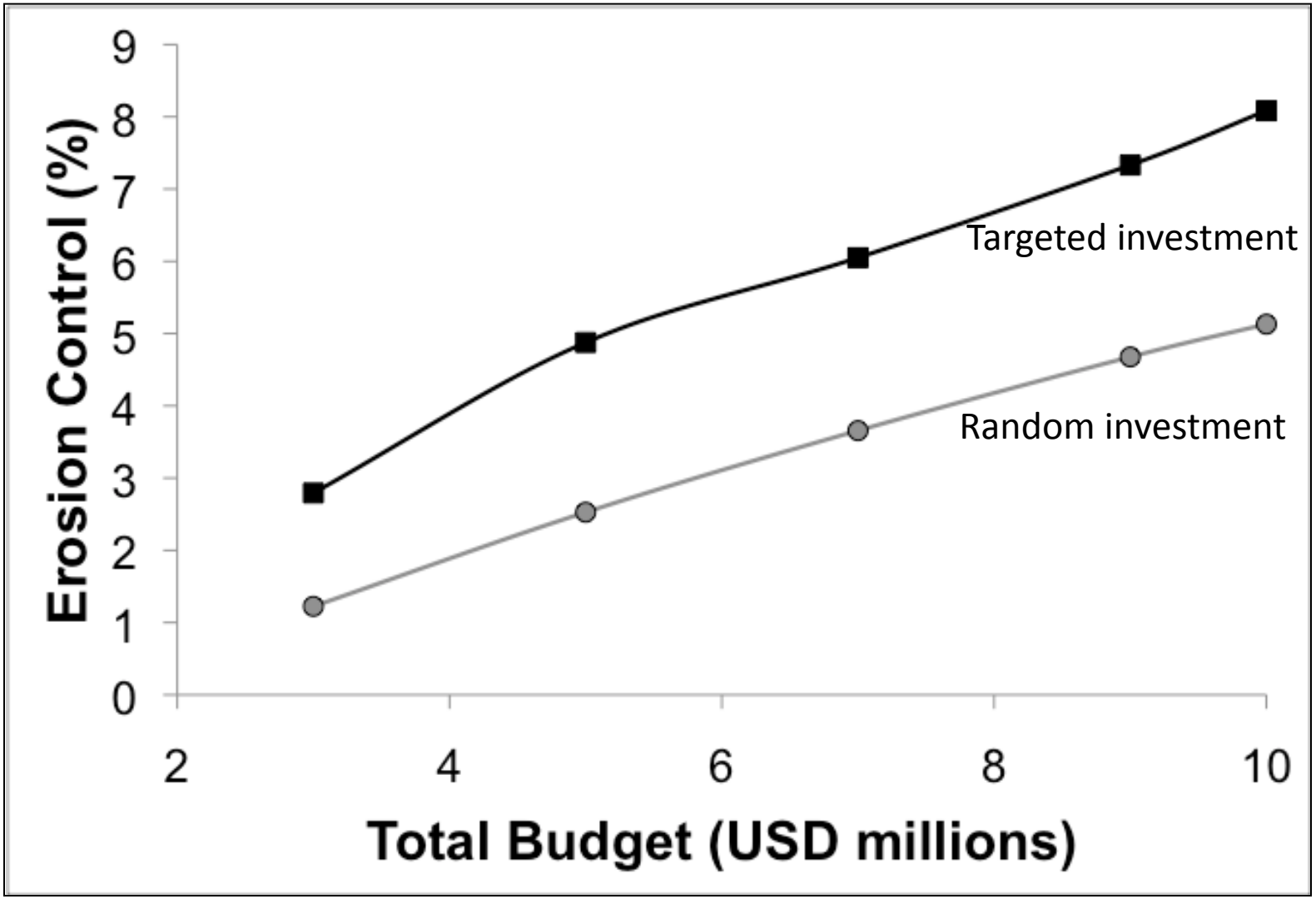
Cost Data



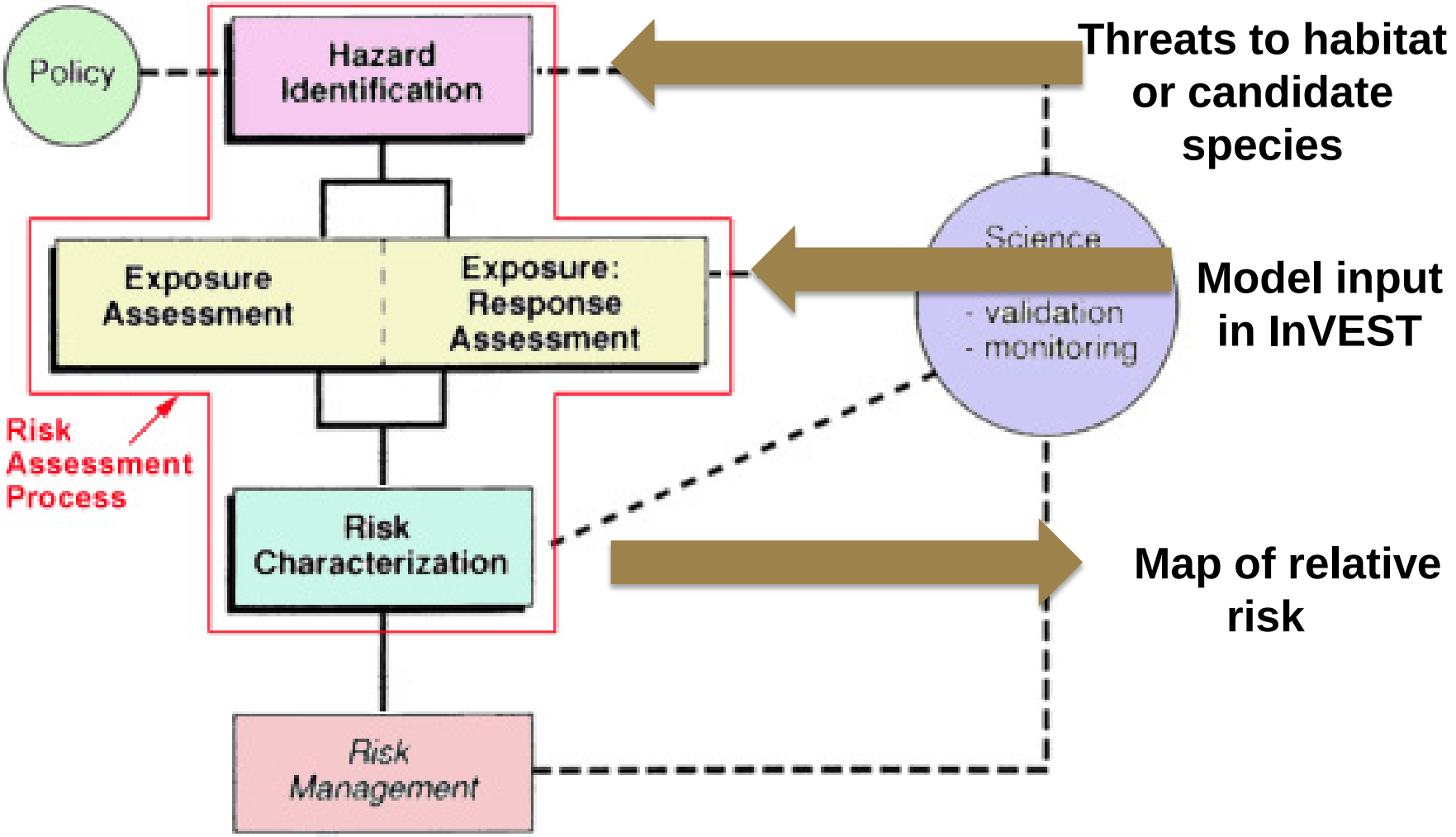
Investment Portfolio



Erosion control returns for targeting investments



Habitat Risk Assessment



Habitat Risk Assessment

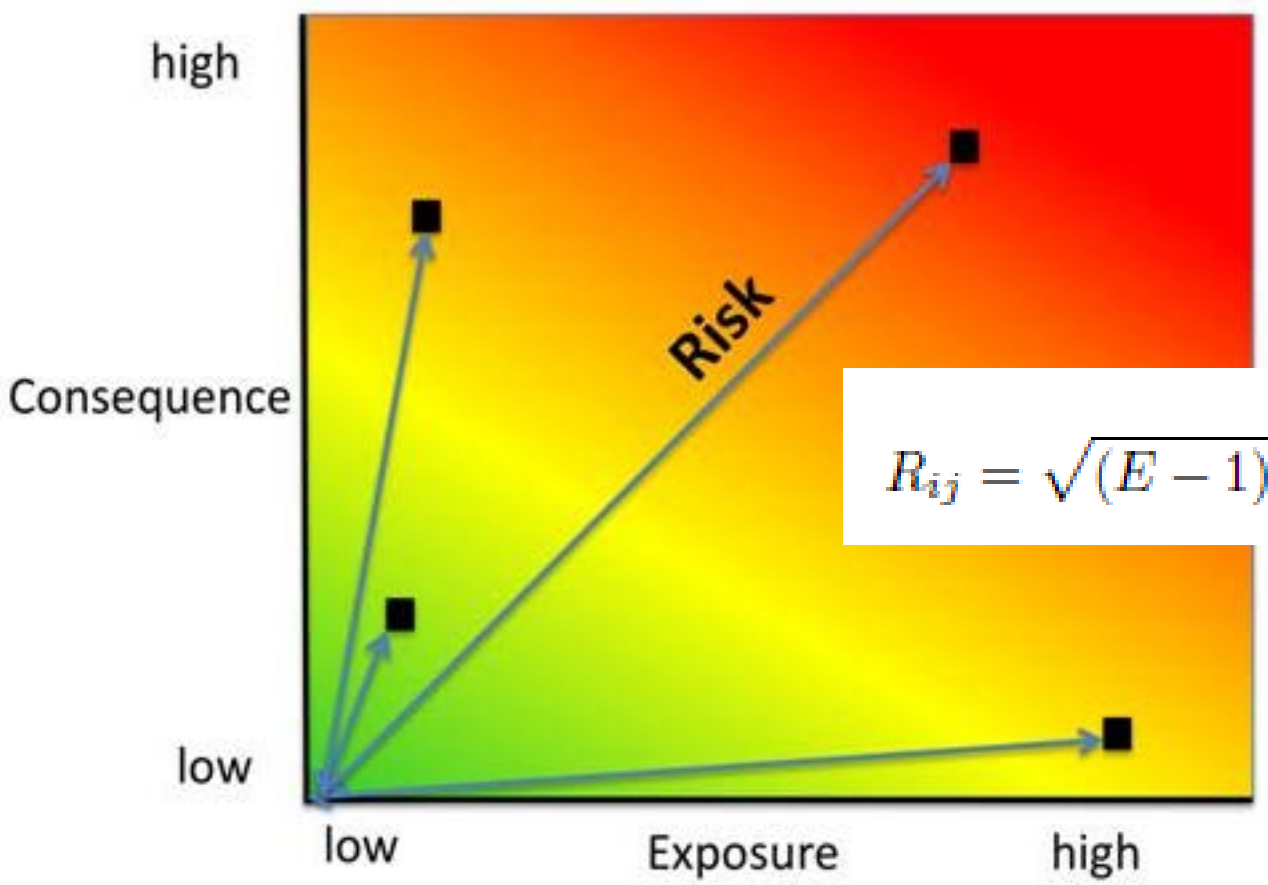
Exposure	
Spatial overlap	3
Temporal overlap	1
Intensity	2
Management effectiveness	3

Weighted average
- ❑ data quality
- ❑ importance

Consequence	
Change in area	3
Change in structure	3
Frequency of natural disturbance	2
Natural mortality	3
Recruitment	1
Age at maturity/ recovery time	1
Connectivity	2

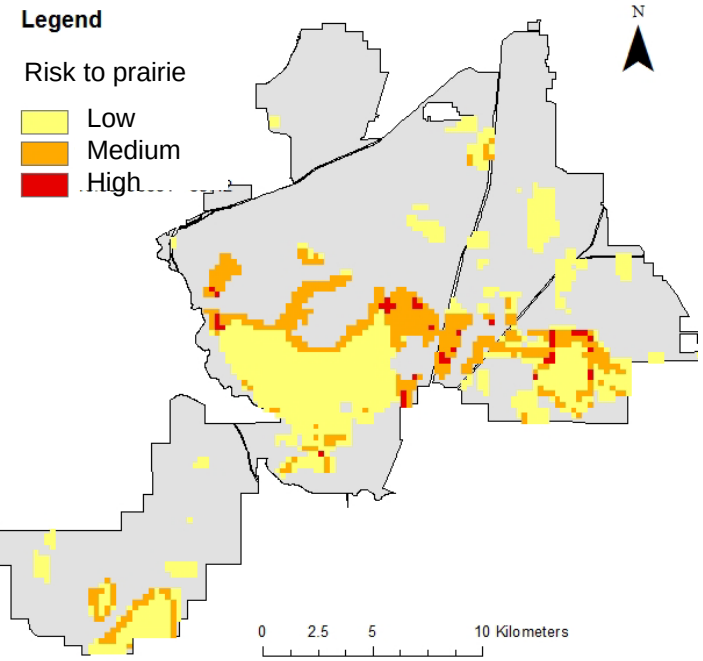
Weighted average
- ❑ data quality
- ❑ importance

Calculation of Risk

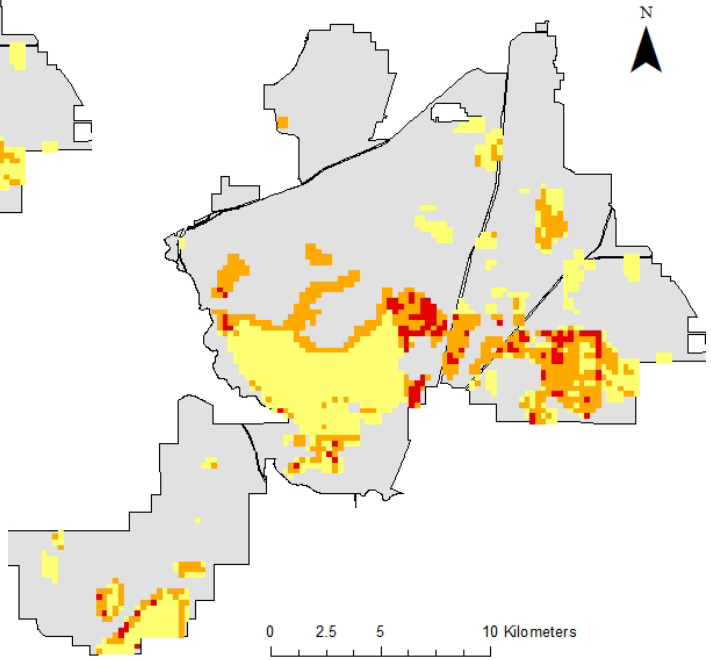


$$R_{ij} = \sqrt{(E-1)^2 + (C-1)^2}$$

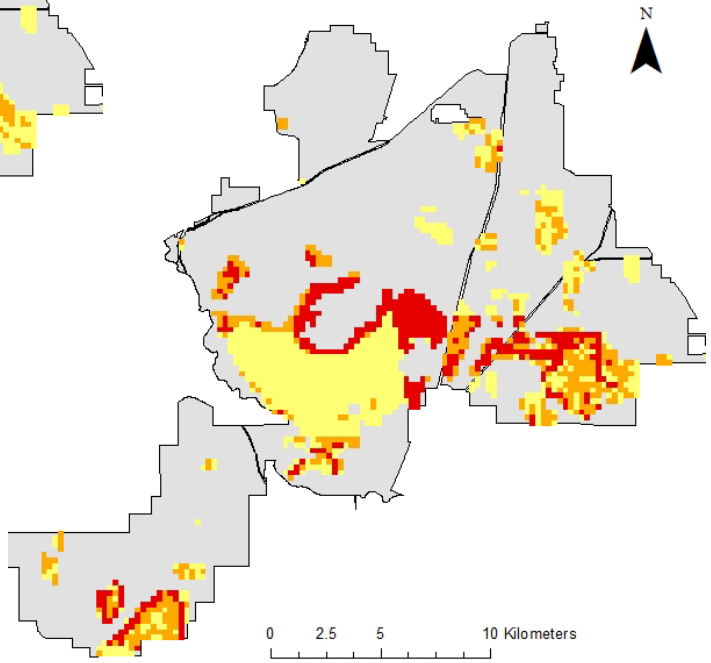
Results: Mapping Risk for Prairie Habitat



Best case



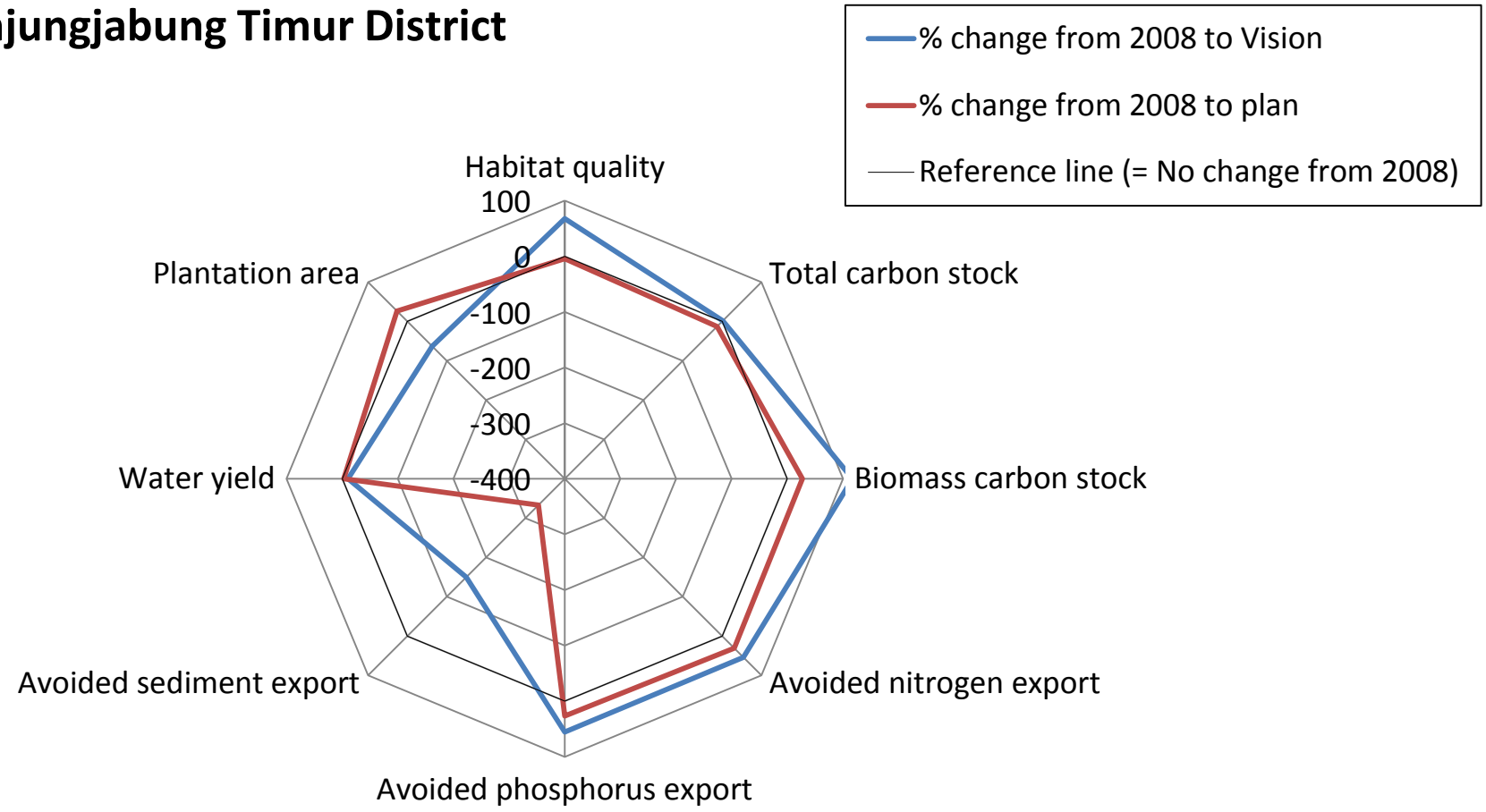
Baseline



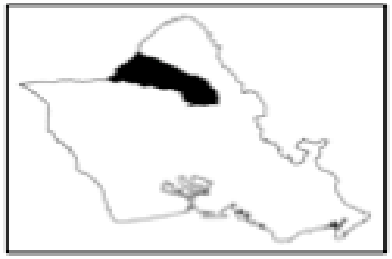
Worst case

Spider web trade-off diagrams

Tanjungjabung Timur District



e.g., Sumatra



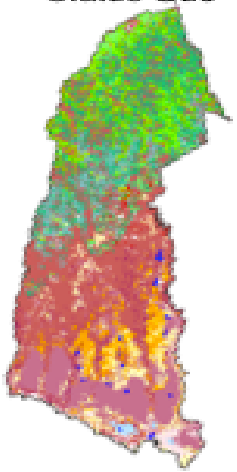
Island of O'ahu

Future Scenarios

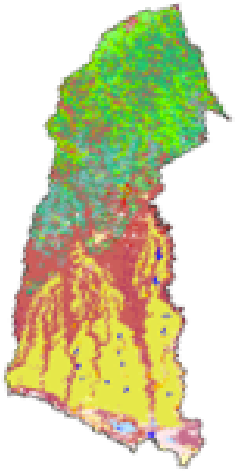
Decision Alternatives

No Irrigation Improvements

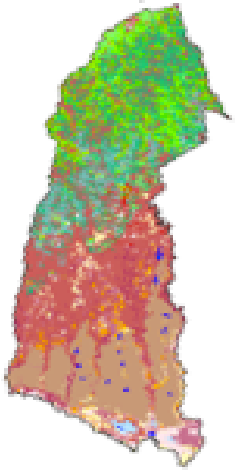
Status Quo



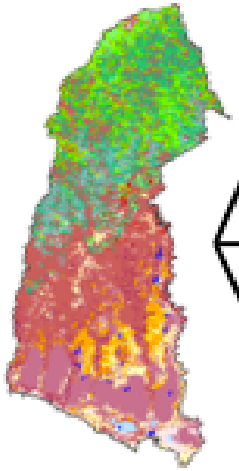
Pasture



Residential Development



Sell Land

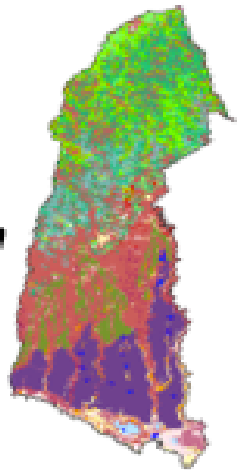


Base Landscape

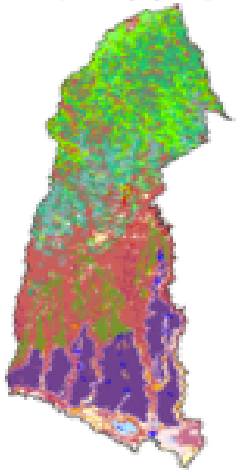
Improve Irrigation System

Food Crops & Forestry

No Field Buffers

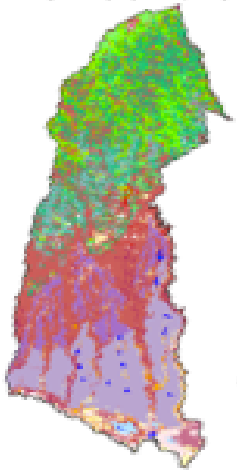


With Field Buffers

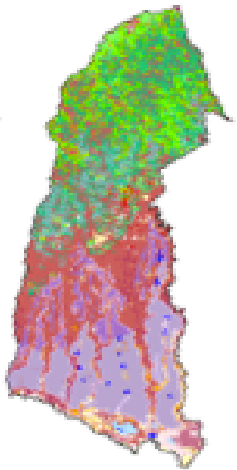


Biofuels (Sugarcane)

No Field Buffers



With Field Buffers



Hawaii

	Carbon Storage	Water Quality	Water Yield	Income
Biofuels 	↓	↓	↓	↑
Subdivision 	↓	↓	↑	↑
Ag & Forestry 	↑	↑	↓	↑

Thanks!

- Questions?

- Contact – Guy Ziv (guyziv@stanford.edu)