# Quantifying and evaluating trade-offs between multiple ecosystem services in Haean Catchment

**TERRECO Workshop, April 2010**

Thomas Koellner, Patrick Poppenborg, Bora Lee, Emily Martin, Stefan Strohmeier, Steve Lindner, Svenja Bartsch, Yohannes Ayanu, Sebastian Arnhold, Marianne Ruidisch, Bumsuk Seo, Andy Choi

Professorship of Ecological Services (PES), University of Bayreuth
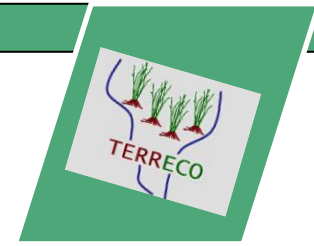
# WHAT ARE ECOSYSTEM SERVICES?

# Complex TERRain and ECOlogical Heterogeneity

## Evaluating ecosystem services in production versus water yield and water quality in mountainous landscapes

### A joint education and research activity between Germany and South Korea (DFG / KOSEF)

## Ecosystem Services in Production

Forest Zone

Dryland Farming Zone
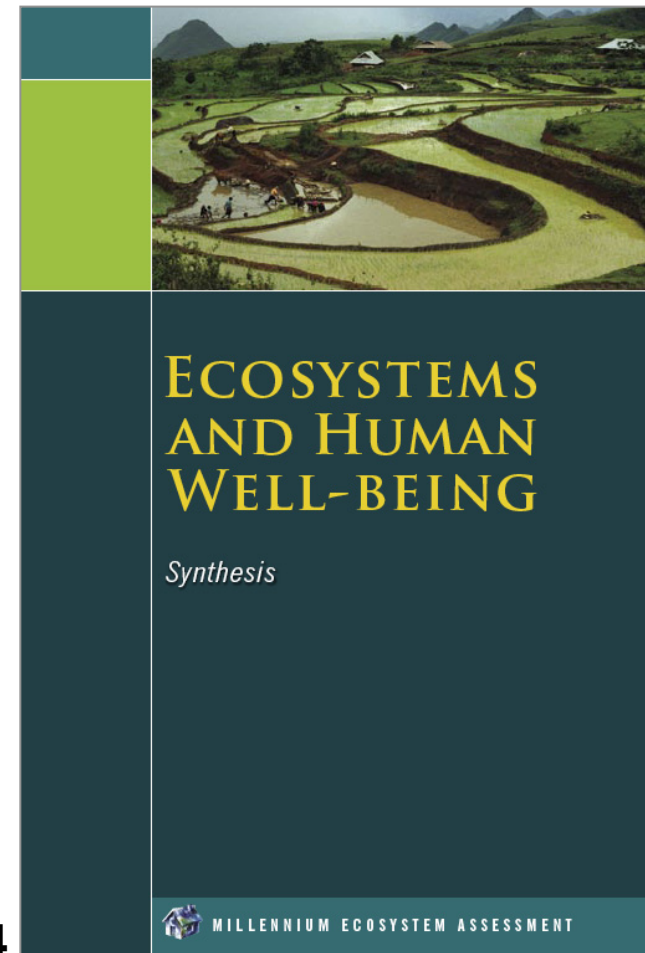
Rice Paddy Zone

Riparian Zone / Stream System
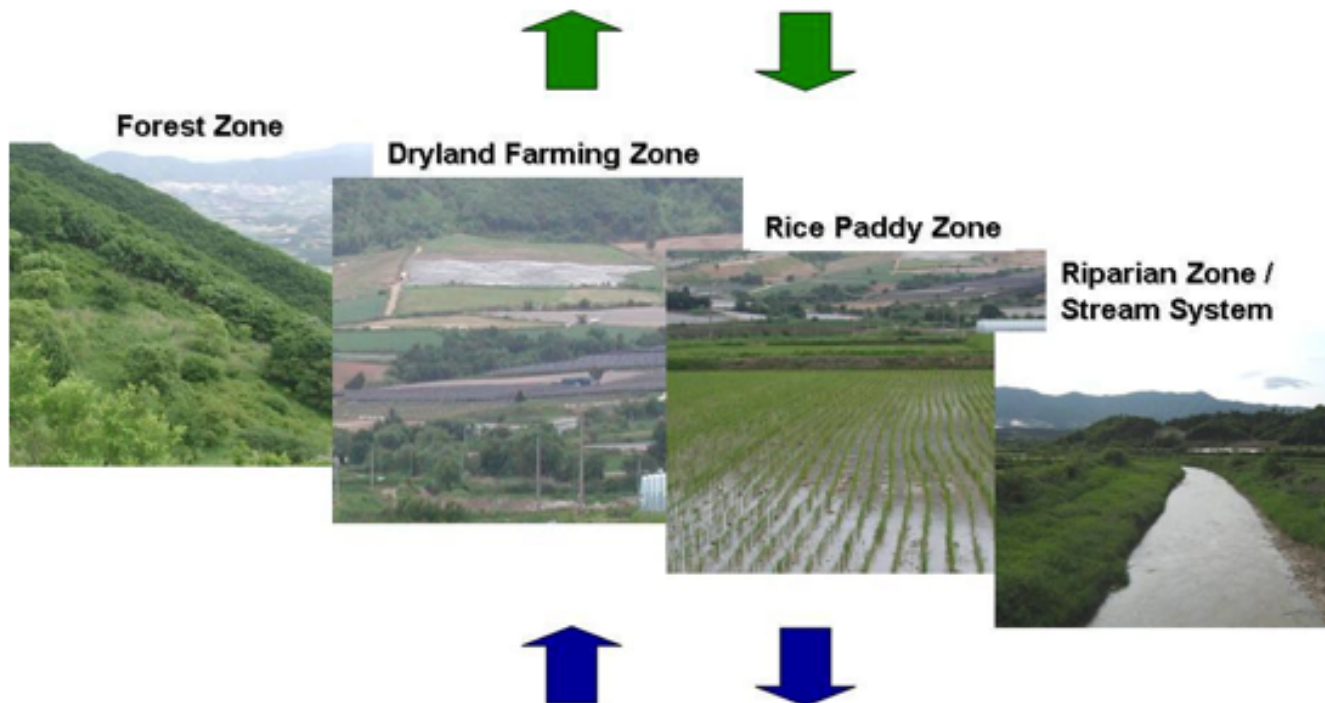
## Services in Water Quality and Yield

*Ecosystem services* are functional properties of ecosystems that contribute to human well-being
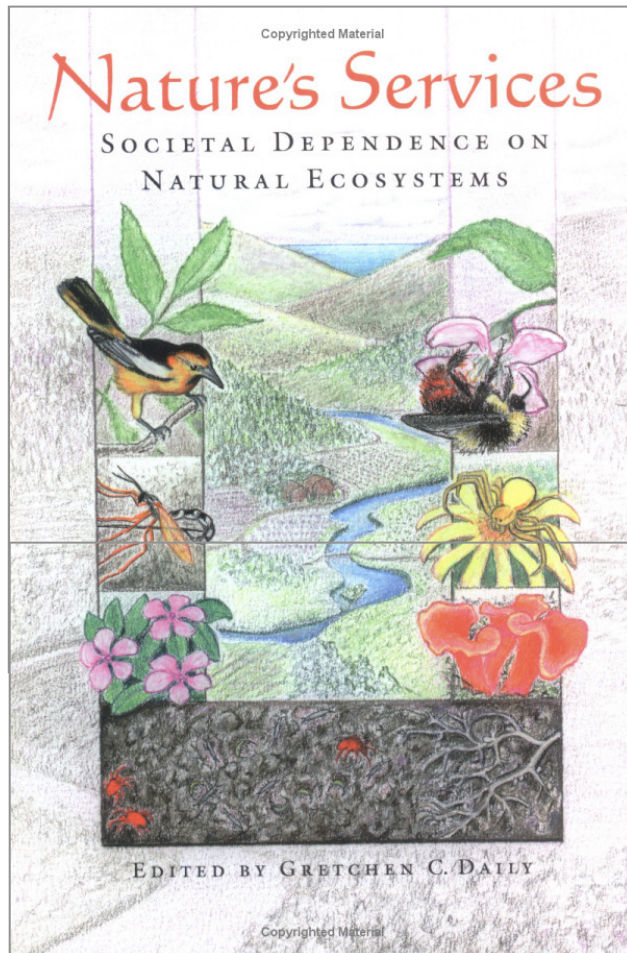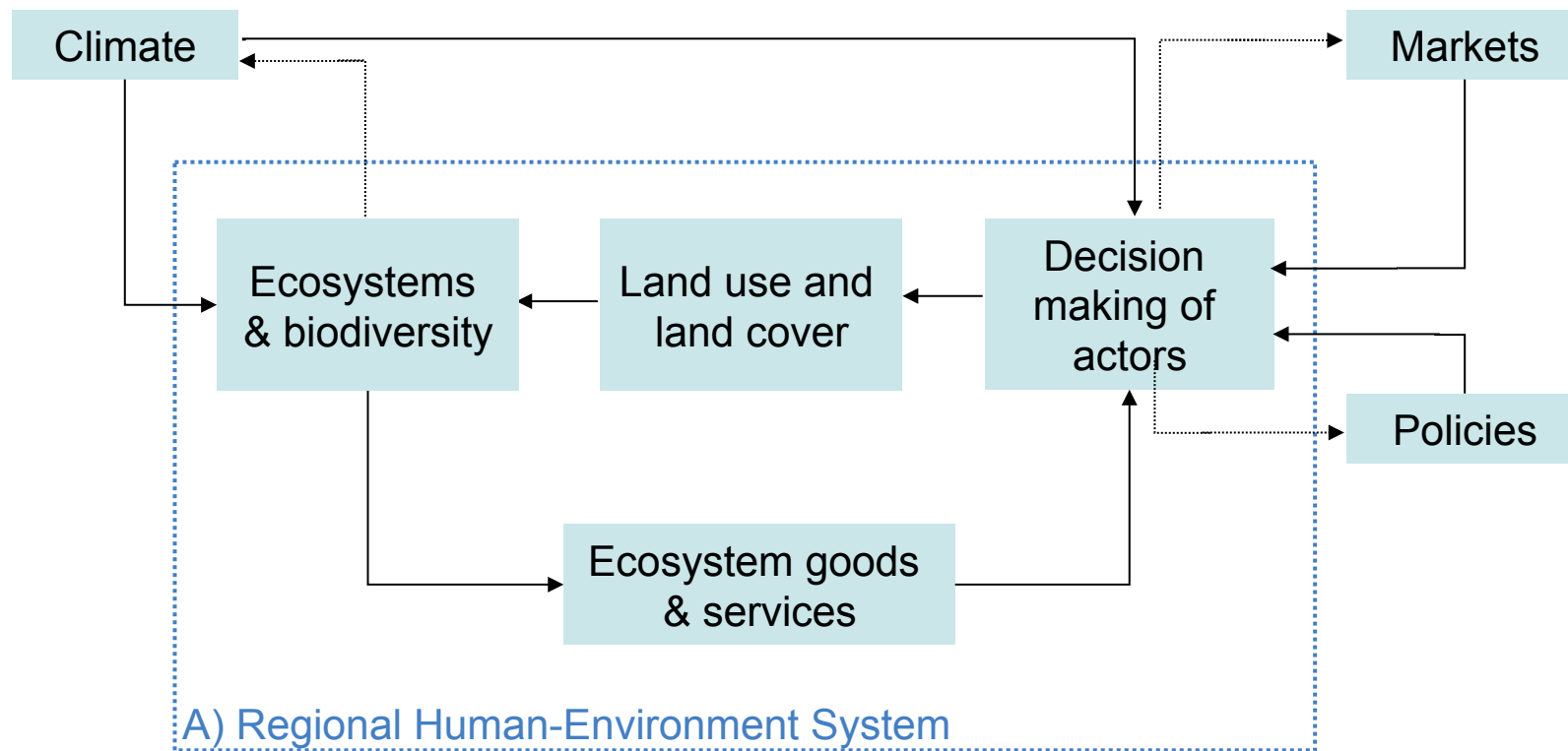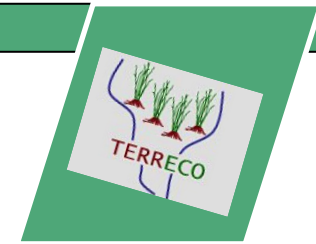

1997


2004

# Ecosystem Services in Human-Environment Systems
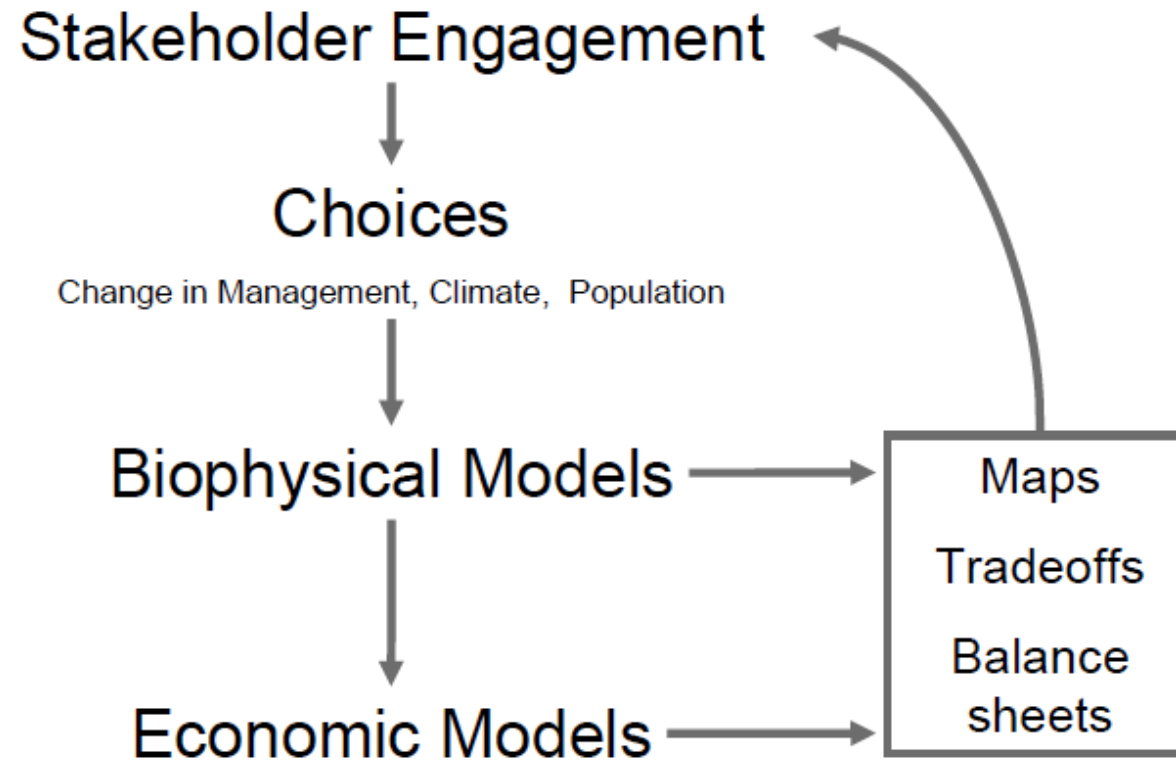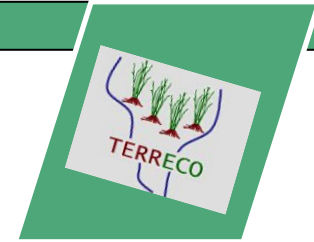


A) Regional Human-Environment System

B) Climate
as Global Driver

C) Markets and Policies
as Global Driver

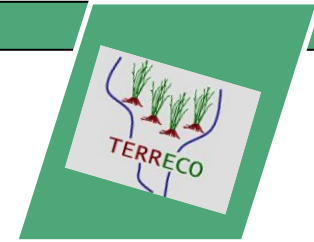# QUANTIFICATION OF ECOSYSTEM SERVICES WITH THE INVEST TOOL

# The InVEST tool:
# Integrated Valuation of Ecosystem Services and Tradeoffs

Stakeholder Engagement

↓

Choices

Change in Management, Climate, Population

↓

Biophysical Models → Maps
Tradeoffs
Balance sheets

↓

Economic Models →

Taken from: InVEST 1.003 BETA User's Guide: Integrated Valuation of Ecosystem Services and Tradeoffs

# InVEST [1.003 Beta]

- … **freely available**, **open source** product by the Natural Capital Project (*http://www.naturalcapitalproject.org/InVEST.html*)

- … runs script tools for the **Arc-GIS ToolBox** environment

- … estimates **amount and value of ES**

- … returns results in either **biophysical or economic terms**

- … generates **spatially-explicit models** based on current landscapes or future scenarios

# InVEST [1.003 Beta] (cont.)
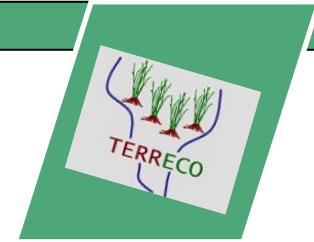
- … currently includes tools (Tier 1 models) for modelling:

    - Biodiversity

    - Carbon storage and sequestration

    - Reservoir hydropower

    - Avoided reservoir sedimentation

    - Managed timber production

    - Crop pollination

- … other services and more sophisticated models (Tier 2 and 3) are expected "soon"

    - Water purification: Nutrient retention now in version 1.004

    - Other expected are flood mitigation, hydropower production, irrigation, agricultural production, open access harvest of timber and NTFP's, recreation and tourism, cultural benefits

# InVEST [1.003 Beta] (cont.)
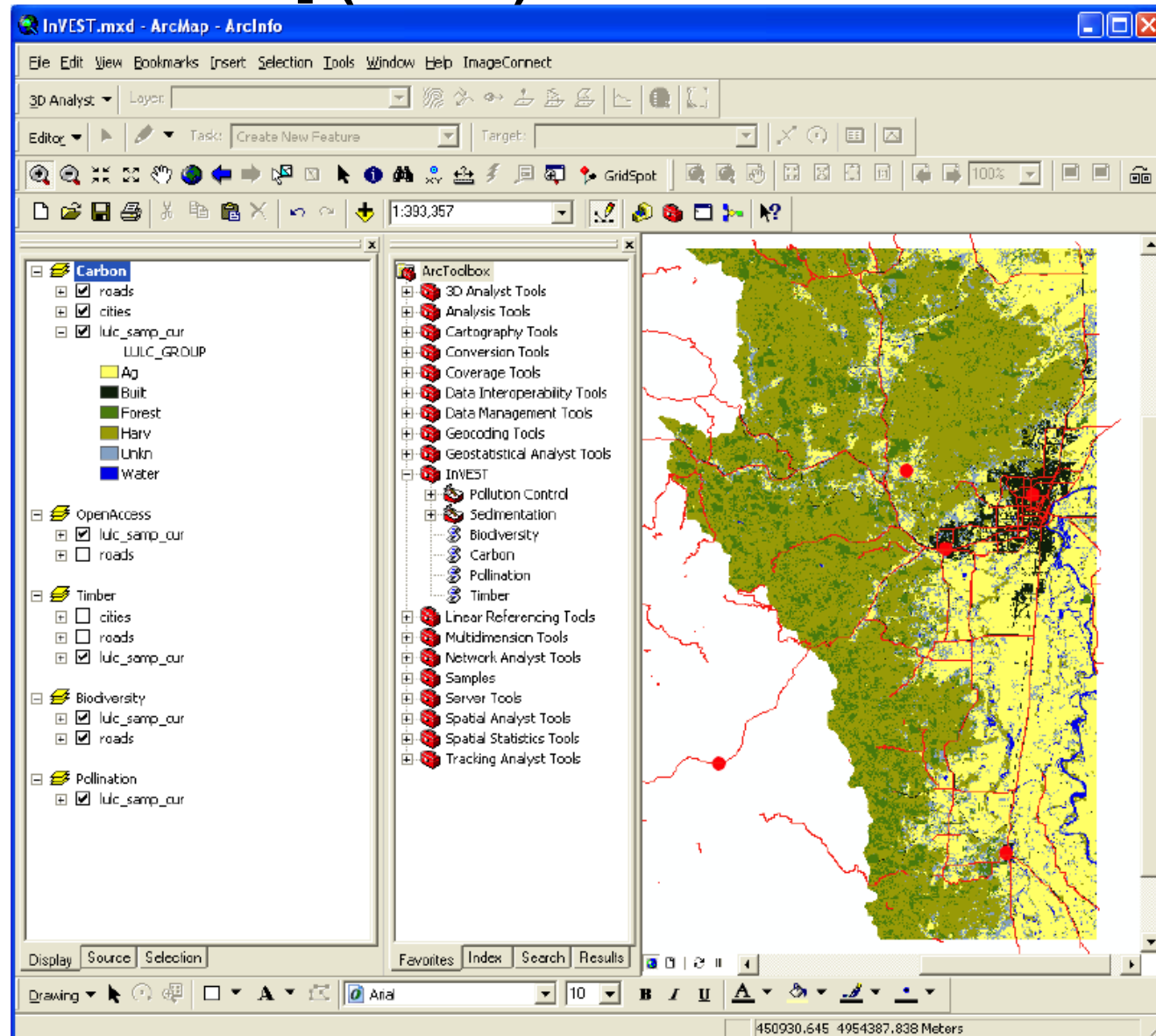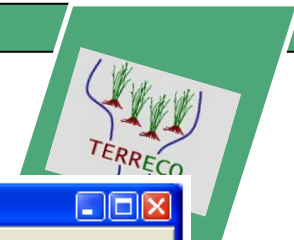


InVEST Toolbox and tools displayed

# Biodiversity model
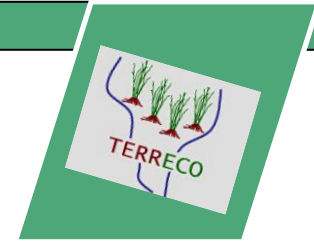
→ Produces maps with indicators between 0 and 1 for

- *Habitat Integrity* (level of threat intensity), and

- *Habitat Rarity* (level of prioritization)

**Data needs**
1. Land use/land cover (LULC) map *(required)*
2. Threats data *(required)*
3. Sensitivity land cover types to each threat *(required)*
4. Threat layer(s) *(required)*
5. Accessibility to sources of degradation *(optional)*
6. Baseline land cover map *(optional)*
7. Weight given to integrity when combined with rarity *(optional)*
8. Future land use *(optional)*

# Carbon storage and sequestration model
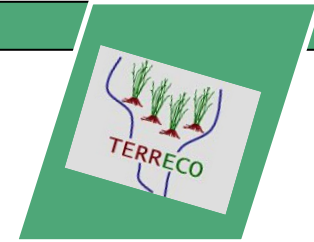
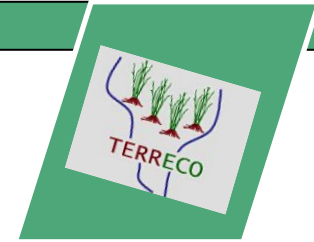→ Produces maps showing carbon storage (expressed as Mg of C or as market value in $) for:

- *Aboveground biomass*          - *Belowground biomass*

- *Soil*                                      - *Dead organic matter*

**Data needs**

1. Land use/land cover (LULC) map *(required)*

2. Carbon pools (Mg/ha)  *(required)*

3. Current harvest rates map *(optional)*

4. Future scenarios *(optional)*

5. Economic data *(optional)*

# Avoided reservoir sedimentation model

→ Calculates annual average soil loss from each land parcel determining:

- *How much soil arrives at a particular* (based on USLE)

- *The ability of each parcel to retain sediment* (in kg)

- *The annual cost of removing the accumulated sediment* (per m³)

**Data needs**

1. Digital Elevation Model *(req.)*

2. Rainfall erosivity index *(req.)*

3. Soil erodibility *(req.)*

4. Land use/land cover map *(req.)*

5. Watersheds *(req.)*

6. Model coefficient table *(req.)*

7. Sediment table *(req.)*

8. Density of settling sediment *(req.)*

9. Threshold flow accumulation *(req.)*

10. Slope threshold *(req.)*

11. Length-slope power variable *(req.)*

12. Length-slope multiplication variable *(req.)*

13. Sediment yield RKLS *(req.)*

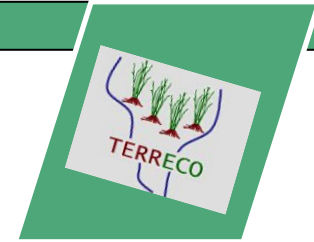14. Sediment yield USLE *(req.)*

# Reservoir hydropower model
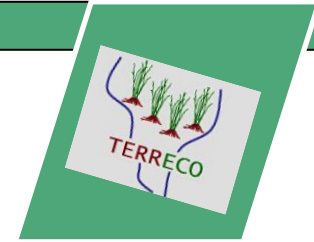
→ Estimates quantity and value of water used for hydropower production from each pixel in three steps:

*1. Determination of water yield*

*2. Calculation of water scarcity value along a flow path*

*3. Estimation of produced energy and its value*

**Data needs**

1. Average annual precipitation
2. Average annual evapotranspiration
3. Soil depth
4. Plant available water content
5. Land use/land cover map
6. Model coefficients table
7. Digital elevation model
8. Saturated hydraulic conductivity
9. Demand table
10. Watersheds
11. Station information table
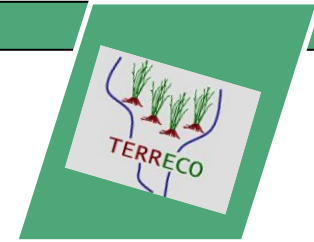
# Managed timber production model

→ Maps Net Present Value of forests' harvests over some user-defined time interval for:

   *- Roundwood harvested by entities with formally recognized harvest rights*

**Data needs**

1. Timber parcels *(required)*

2. Production table *(required)*
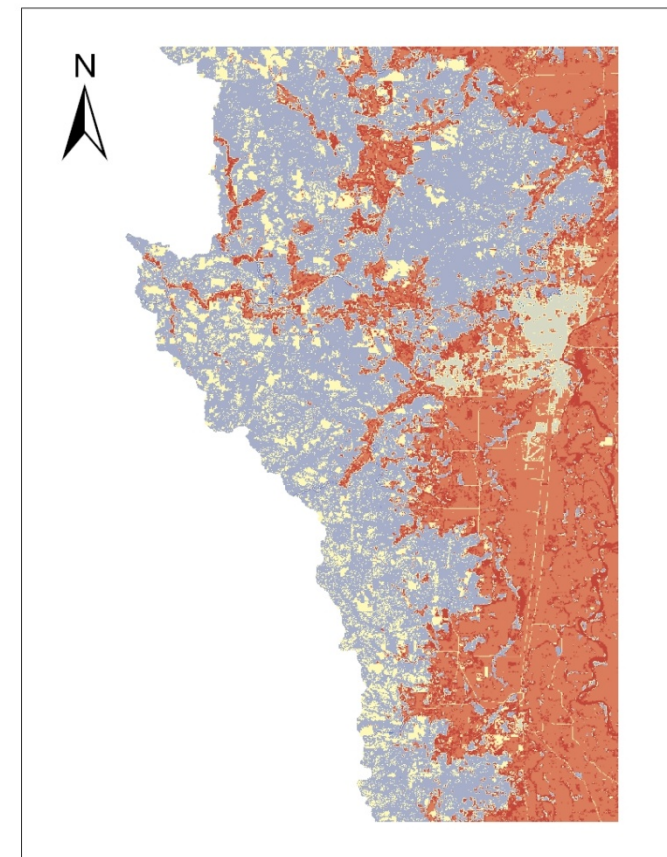
3. Market discount rate *(required)*

# Crop pollination model

→ Maps an abundance index (0-1) for:

   - *Each species available for pollinating*

*crops*

**Data needs**

1. Land use/land cover map *(required)*

2. Table of pollinator species or guilds *(required)*

3. Table of land cover attributes *(required)*

4. Farms *(optional)*

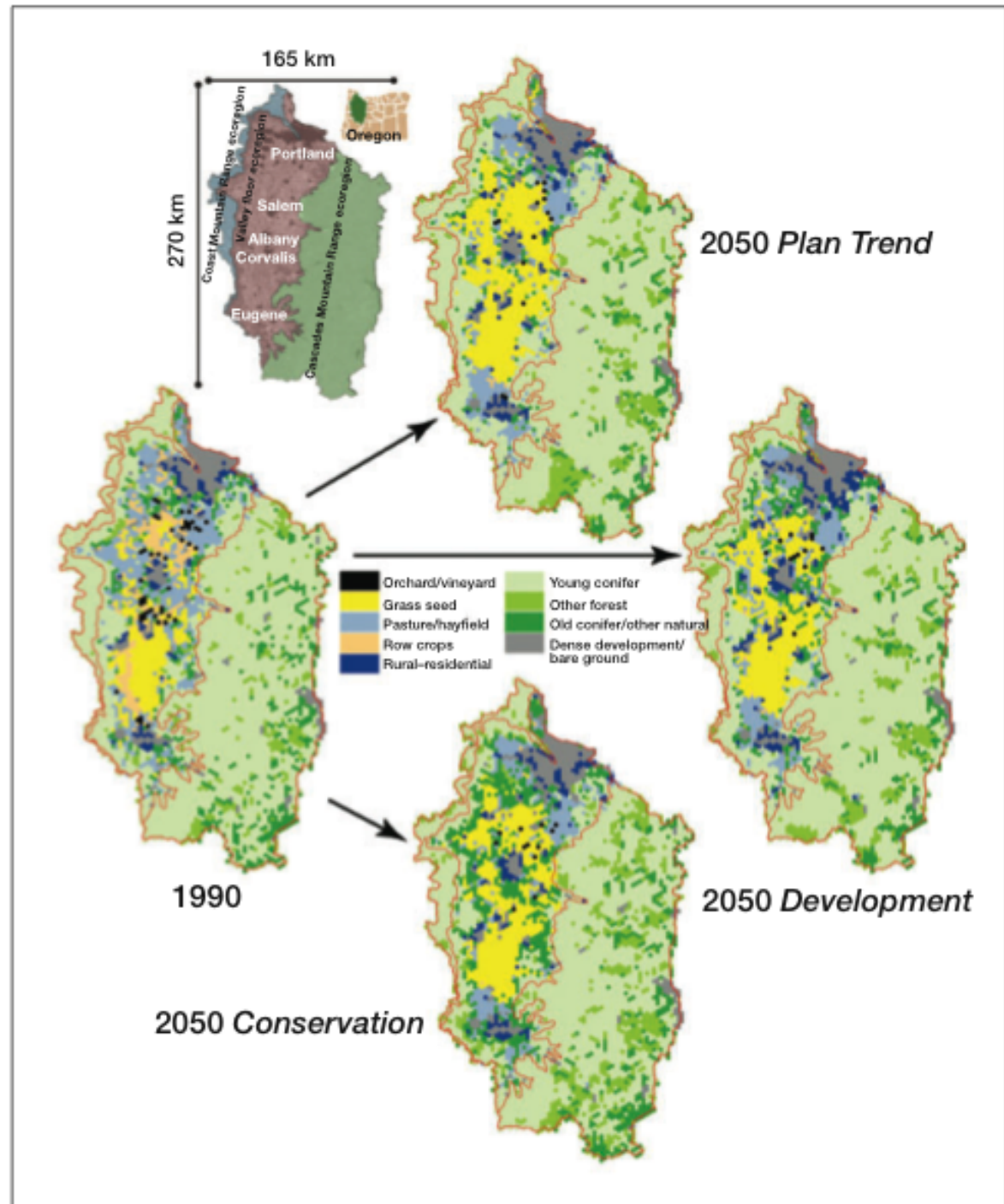5. Future scenarios *(optional)*



Exemplary output of InVEST
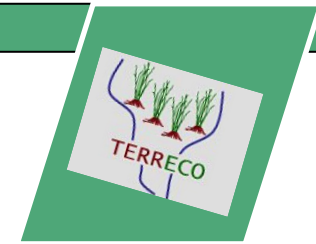
# THE OUTPUT OF THE INVEST TOOL

# Scenarios of land use



Literature: Nelson, E. et al. 2009..

# Mapping of ecosystem services

- InVEST tool parameterize for catchment

- Scenarios for ES can be calculated and mapped

Literature: Nelson, E., et al.2009. Modeling multiple ecosystem services, biodiversity conservation, commodity production, and tradeoffs at landscape scales. Front Ecol Environ 7:4-11.



**Figure 4.** Maps of change in ecosystem services, biodiversity conservation, and market value of commodity production from 1990 to 2050 for the three LU/LC change scenarios. Carbon sequestration and commodity production values are not discounted.

# Scenarios of ES development



Literature: Nelson, E. et al. 2009.

# WORK IN TERRECO

# The expected output
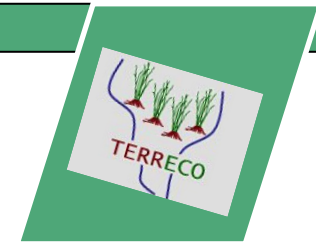
- InVEST tool applied to Haean catchment
  - Link to land use scenarios
  - Scenarios for ES calculated and mapped

- InVEST reliability and validity tested with
  - SWAT model results
  - Pixgro model results
  - Field data

- Improvements of InVEST tool elaborated
  - Probabilistic land use decision making model
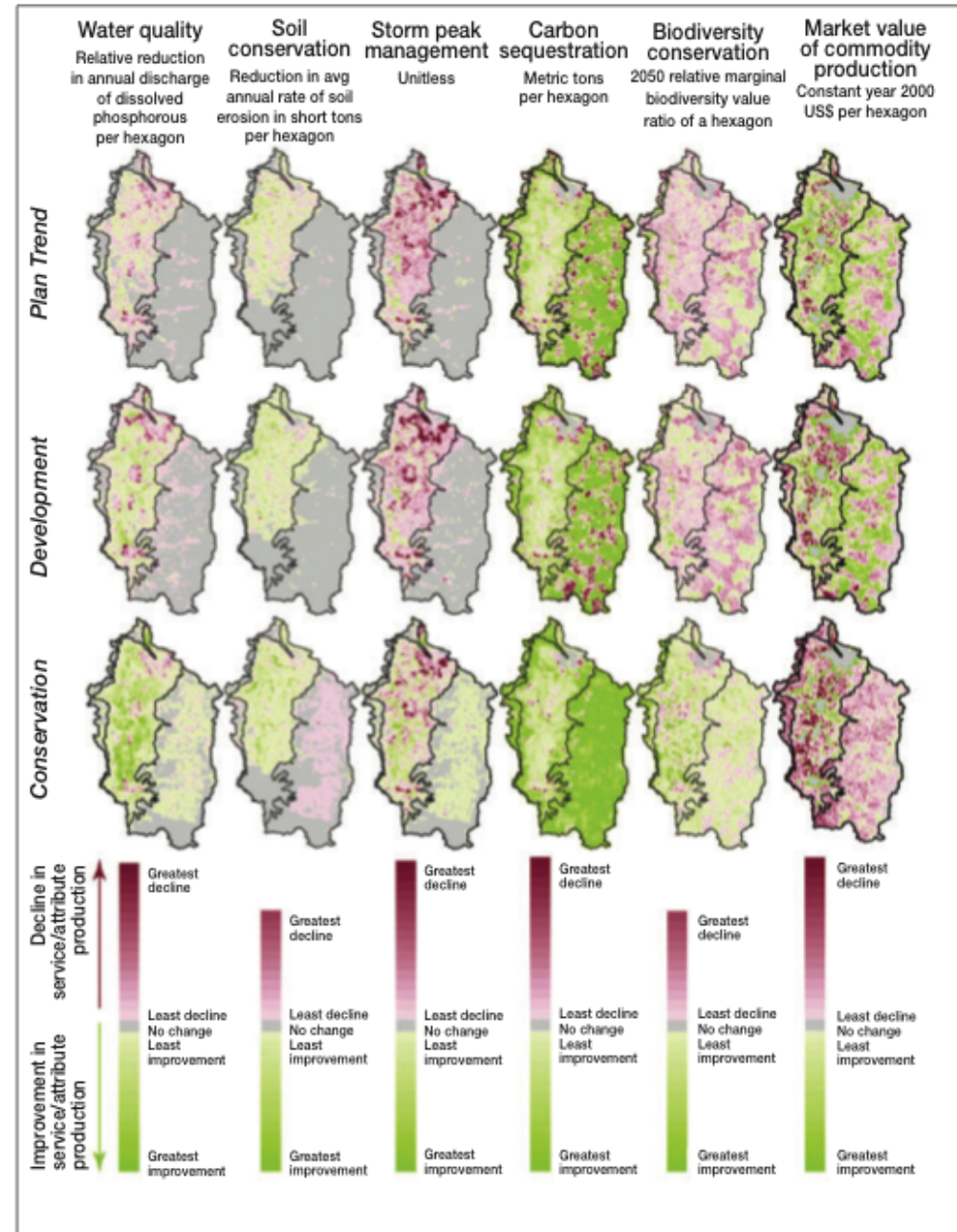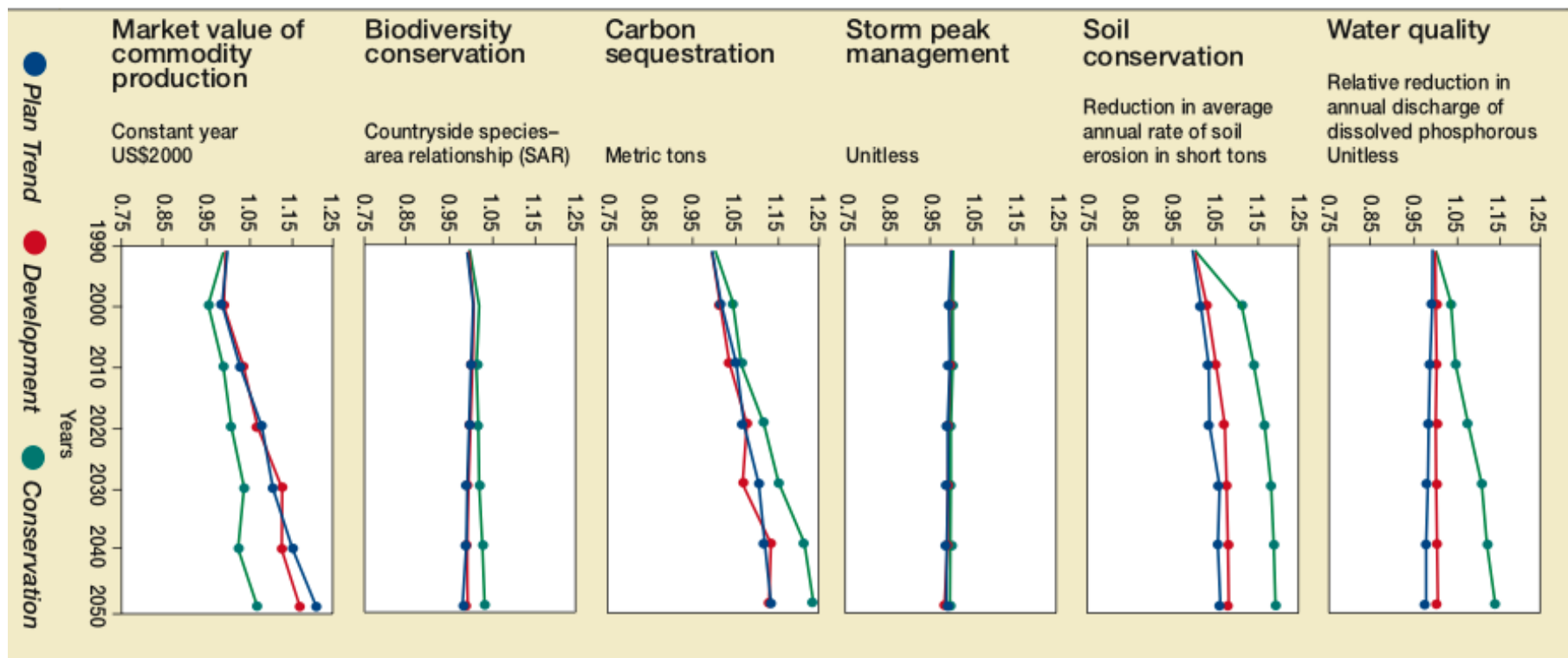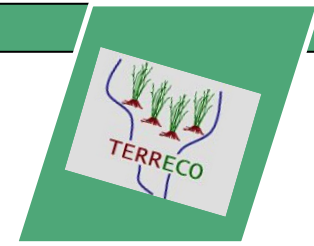  - Probabilistic ES model
  - Economic valuation



**Figure 4.** Maps of change in ecosystem services, biodiversity conservation, and market value of commodity production from 1990 to 2050 for the three LU/LC change scenarios. Carbon sequestration and commodity production values are not discounted.

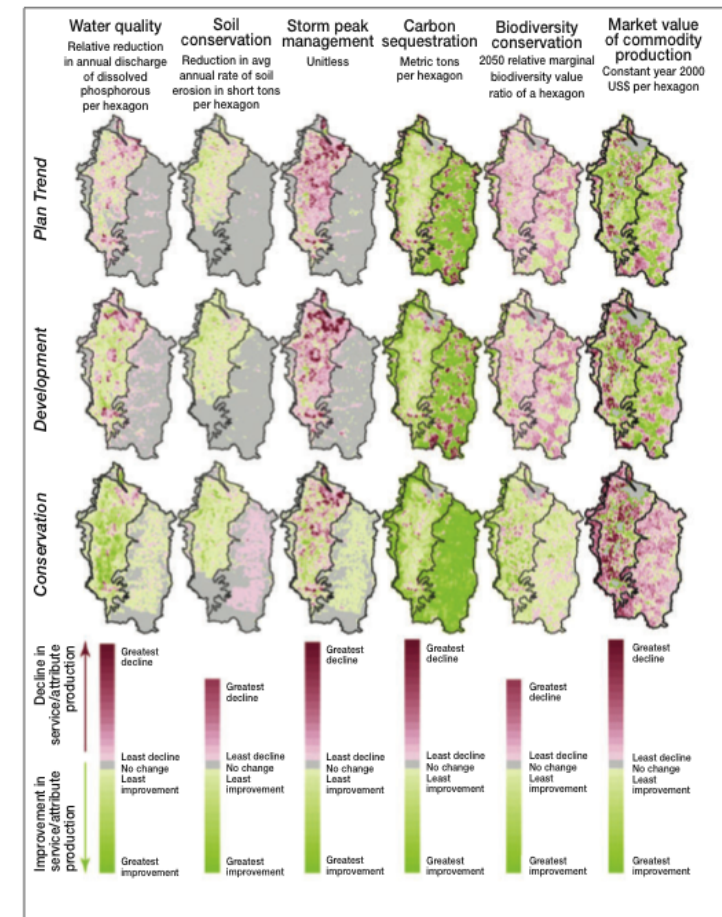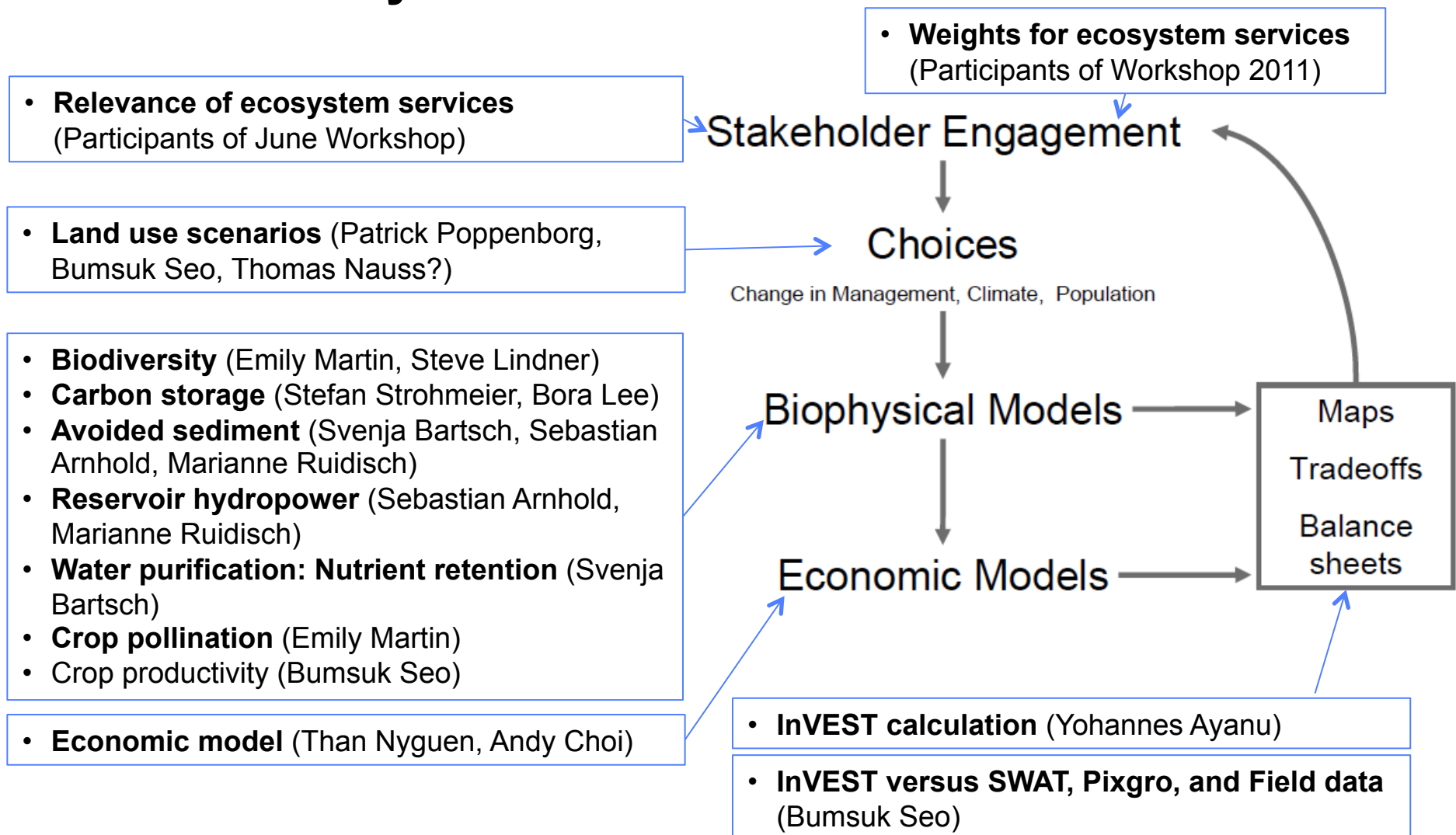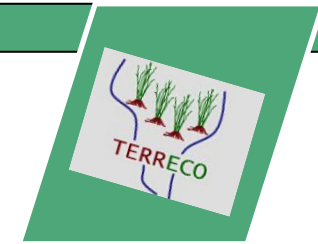# Interdisciplinary work on the InVEST tool by the TERRECO team

• **Relevance of ecosystem services** (Participants of June Workshop)

• **Land use scenarios** (Patrick Poppenborg, Bumsuk Seo, Thomas Nauss?)

• **Biodiversity** (Emily Martin, Steve Lindner)
• **Carbon storage** (Stefan Strohmeier, Bora Lee)
• **Avoided sediment** (Svenja Bartsch, Sebastian Arnhold, Marianne Ruidisch)
• **Reservoir hydropower** (Sebastian Arnhold, Marianne Ruidisch)
• **Water purification: Nutrient retention** (Svenja Bartsch)
• **Crop pollination** (Emily Martin)
• Crop productivity (Bumsuk Seo)

• **Economic model** (Than Nyguen, Andy Choi)

• **Weights for ecosystem services** (Participants of Workshop 2011)

Stakeholder Engagement

↓

Choices

Change in Management, Climate, Population

↓

Biophysical Models →

↓

Economic Models →

Maps
Tradeoffs
Balance sheets

• **InVEST calculation** (Yohannes Ayanu)

• **InVEST versus SWAT, Pixgro, and Field data** (Bumsuk Seo)

**Next meeting of the InVEST group**

**Thursday, April 15, 11:00**

**B13**

Task was to read chapter in InVEST report and think about provisioning of data for the variables in Haean catchment