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Rural Livelihood, Biodiversity and Carbon Stock in Vietnam Mountains: Agent-Based Modeling to Anticipate Trade-Offs

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Abstract: Assessment of future multiple ecosystem services driven by alternative land-use policies is useful for supporting decisions about what and where to invest for the best overall environmental and developmental outcomes. The task faces a great challenge due to the inherent complexity of human-landscape systems and trade-offs between rural livelihood improvement, biodiversity conservation and carbon sequestration. Agent-based system models have been recognized to be well suited to simulate the co-evolutions of the community and landscape systems in response to policy interventions. The study applies the Land Use Dynamics Simulator (LUDAS) framework to a mountain watershed in central Vietnam for anticipating trade-offs among rural livelihoods, forest biodiversity and carbon stocks under different land-use policy interventions. Changes in plant species diversity driven by land cover change were calculated using the species-area relationships that were estimated based on vegetation surveys. Total species pool of the study area was calculated with a taking into account of species' turning over different vegetation cover types. Carbon stocks of different forest types were estimated by empirical allometric equations. Our purpose is to assess relative impacts of policy interventions by measuring the long-term landscape and community divergences (compared with a baseline) driven from the widest plausible range of options for a given policy. We design experiments of replicated simulations for relevant policy factors in the study region that include (i) forest protection zoning, (ii) agricultural extension and (iii) agrochemical subsidies. We comparatively assessed trade-offs and synergies between different expectations - i.e. household income and income equity, deforestation and natural vegetation recovering, and forest tree species diversity - driven by different policy interventions. Transparent and objective communication of these informative findings would help increase the effectiveness of multi-stakeholder discussions.

***Keywords**:* Agent-based model, decision support, ecosystem services, household decision making, land-use/cover change, livelihood, species diversity, carbon stock, trade-offs, land use policy

RESEARCH PROGRAM ON Dryland Systems

Food security and better livelihoods for rural dryland communities

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International Center for Agricultural Research in Dry Areas (ICARDA)

iEMSs 2016
Toulouse, 13 July 2016

www.drylandsystems.cgiar.org

Motivation

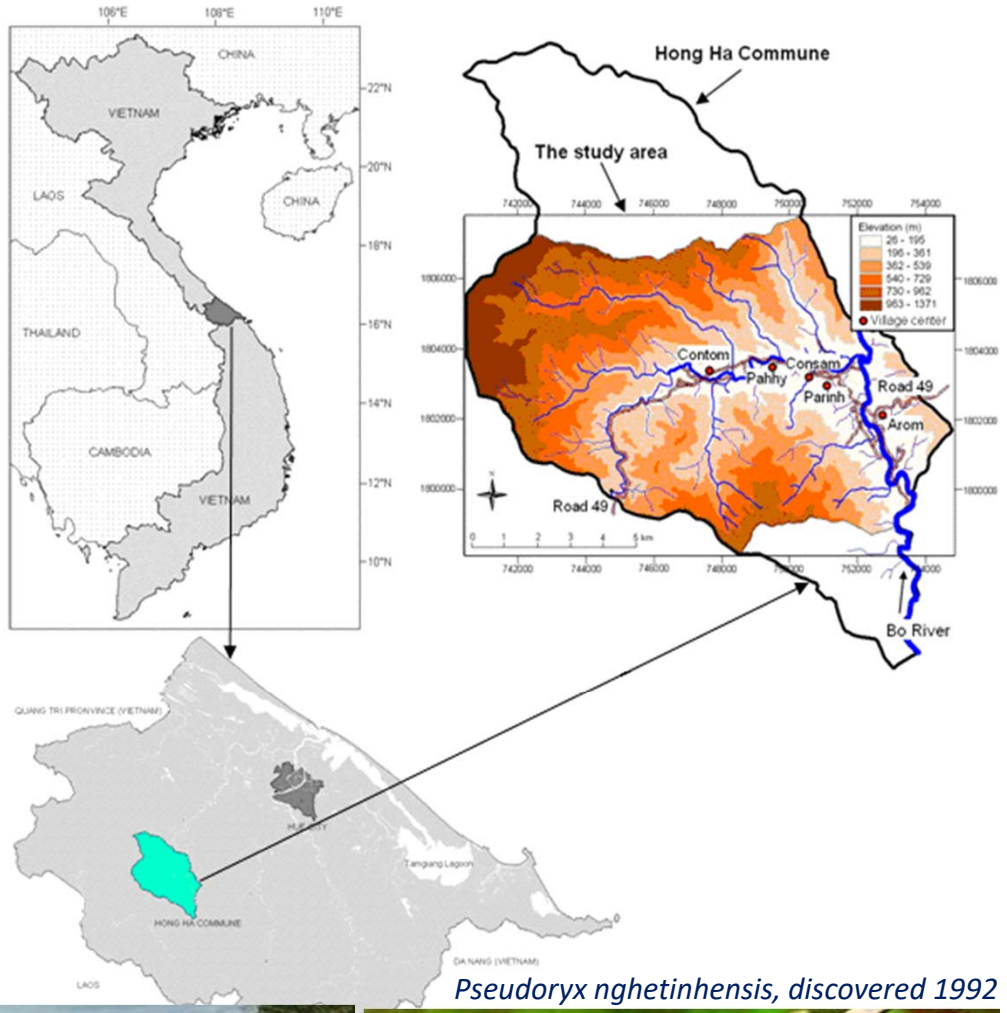
- Dually grand needs in Vietnam mountain: both enhanced rural livelihoods and natural resources

- A true challengle is to anticipate the likely livelihood and environmental impacts of land management/policy interventions

  → inform stakeholders‘ dicussion and decision-making.

Study Areas

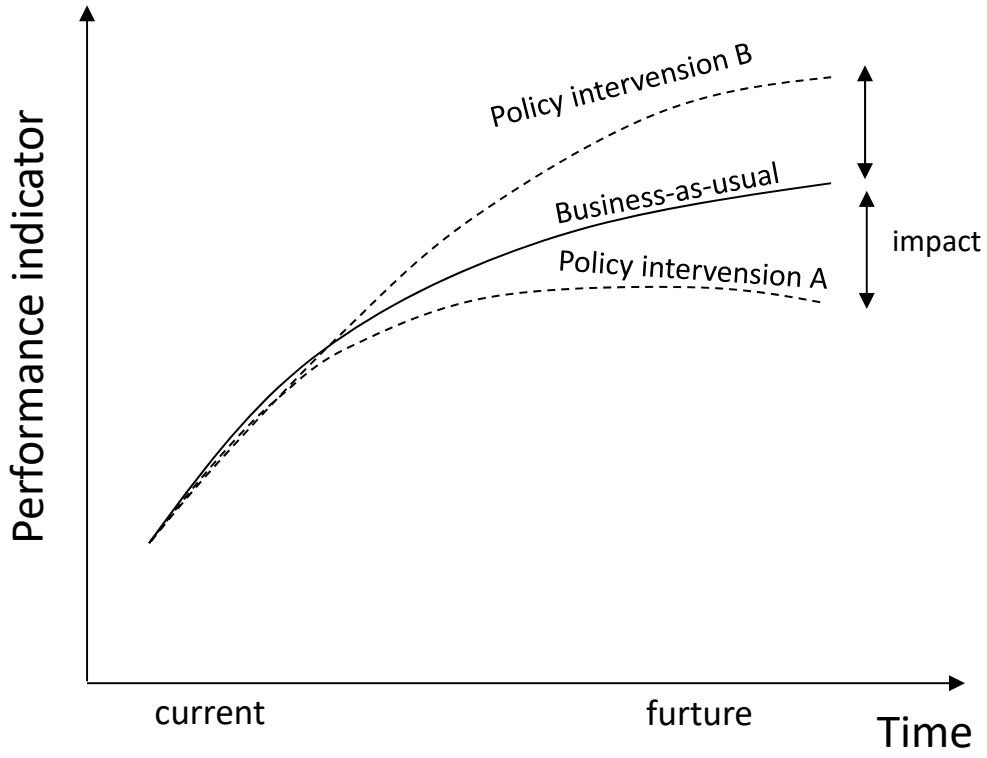
- ~ 100 km^2 of protected mountain watershed in tropical forest zone
- Villigers as agriculture- and forest-dependents
- Concerns in policy decisions in management options for:
  - Forest/widelife protection
  - Agricultural extension and subsidies



Pseudoryx nghetinhensis, discovered 1992

Aims

To assess relative impacts of policy interventions by measuring the **long-term landscape-community divergences** driven from the widest plausible range of options for given land-use policies, thereby informing decision-makers about land use management and planning



Specific objectives:

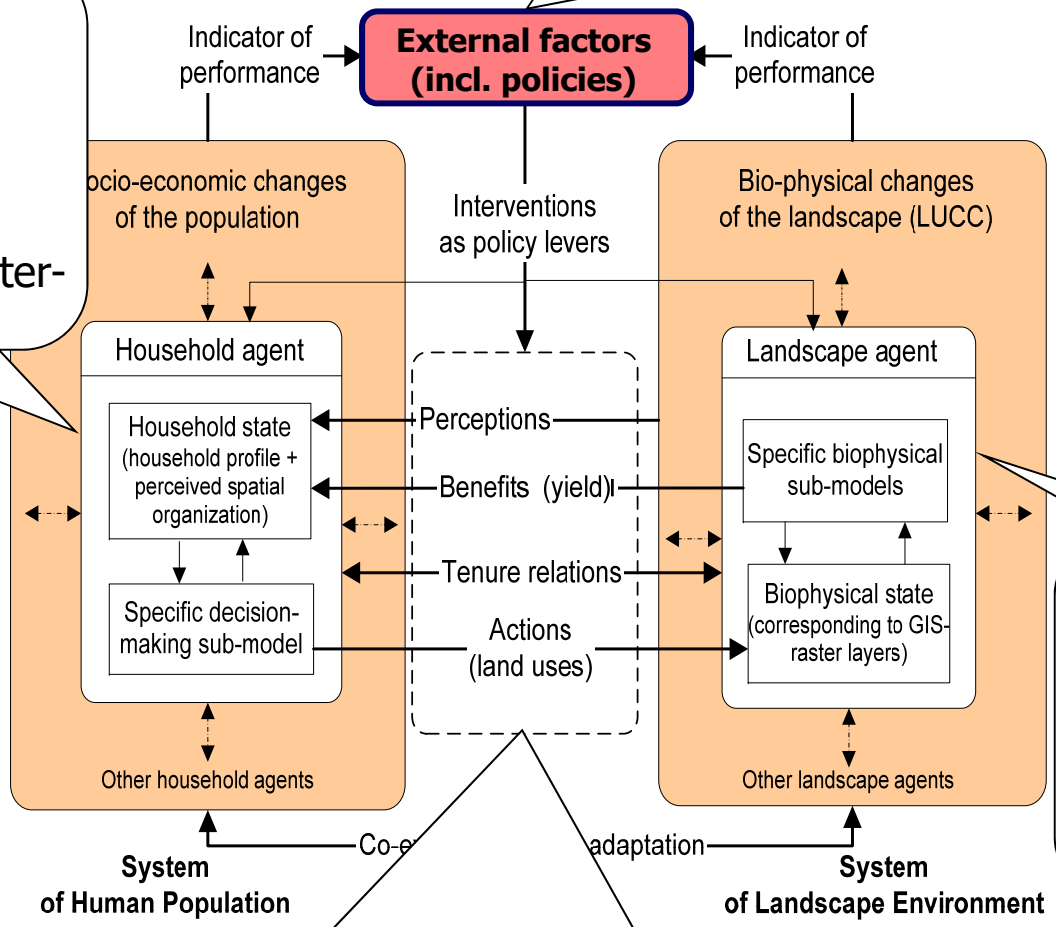
- ***explore*** the magnitude of possible socio-ecological changes
- ***identify*** the most affected system's components (what), locations (where) and periods (when)
- ***highlight*** sound policy interventions (enhanced environmental, socio-economic benefits + least cost in a long run)

LUDAS - Spatially explicit ABM model

Changes in policies modify the human-environment relationship, thus affecting system performance

Household agent integrates:
- personal
- environmental
- policy

information in land/water-use decisions

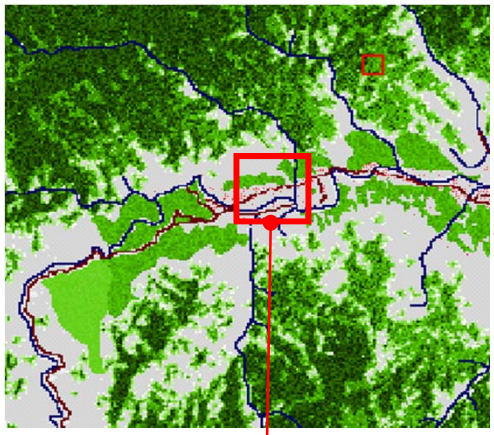


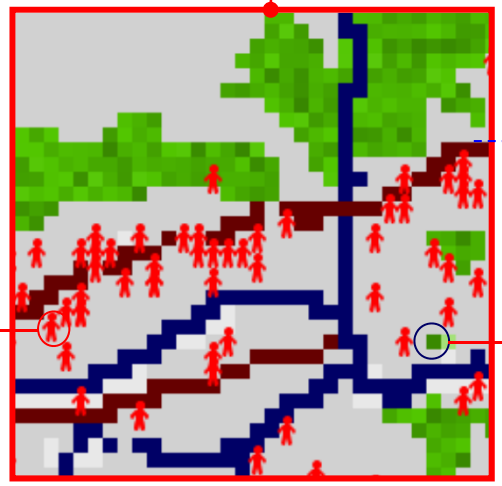
Landscape agent hosts dynamic natural processes responding to local conditions and land-use activities

Information inter-flows between households and their surrounding, land tenure relations, and land-use activities

Le et al. (2008, 2010)

Multi-scale feedback loops in LUDAS





Landscape/Community dynamics

Feedback (constraints/opportunities)

Temporal accumulation

Spatial aggregation

Neighbourhood dynamics

Feedback (constraints/opportunities)

Temporal accumulation

Spatial aggregation

Agent dynamics

Household agent

Household variables

Decision-making models

Tenure relationships

Land-use activities

Investment – Benefit

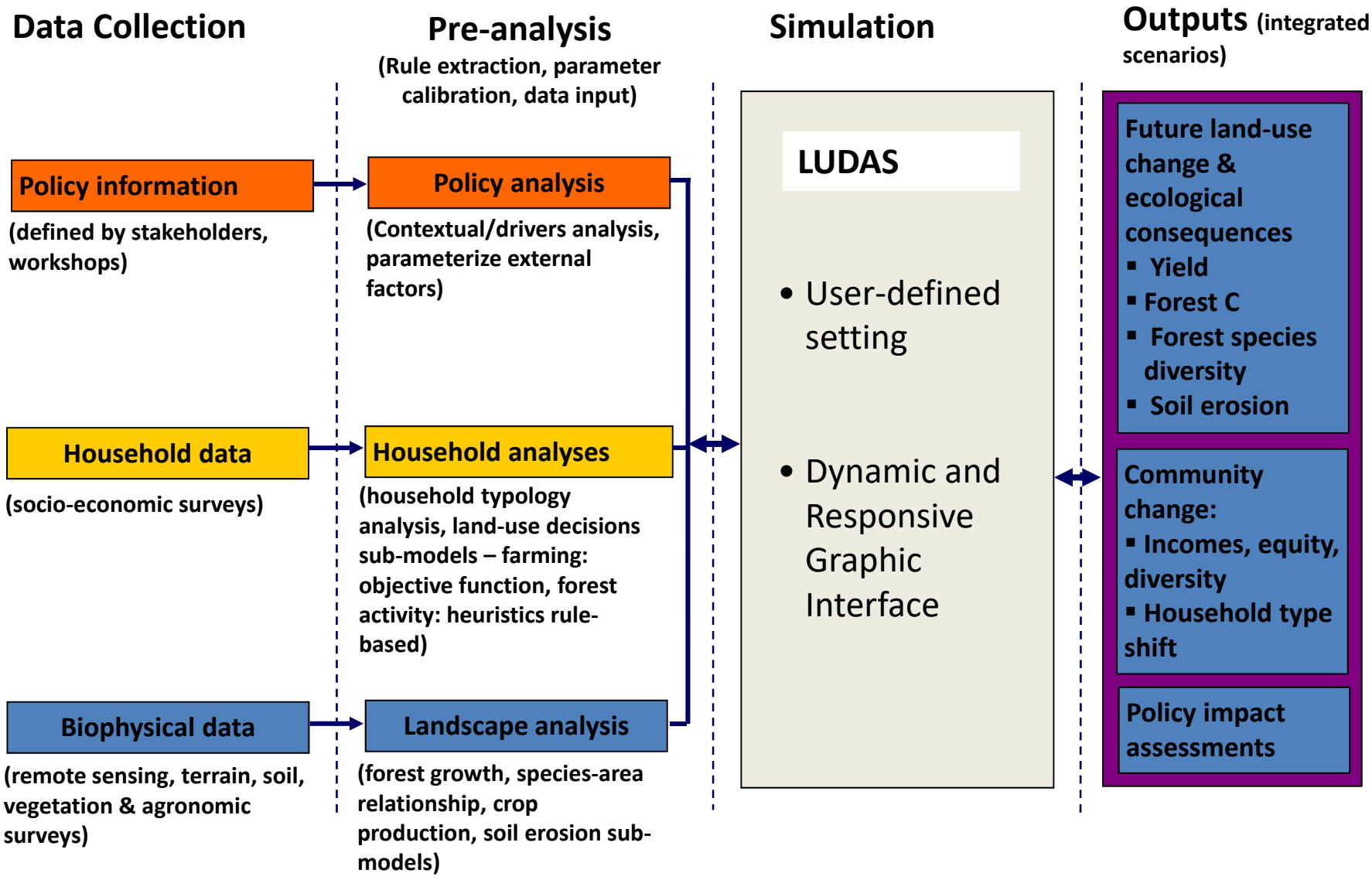
Landscape agent

Ecological variables

Ecological models

Le *et al*. (2008)

Information and analytical flows in LUDAS



Validation tests

Because LUDAS belongs to the class of complex human-environmental systems models, its validity cannot be achieved by point-to-point history matching, but rather a series of tests that could increase the user's confidence in the usefulness of the model.

Model testing includes:

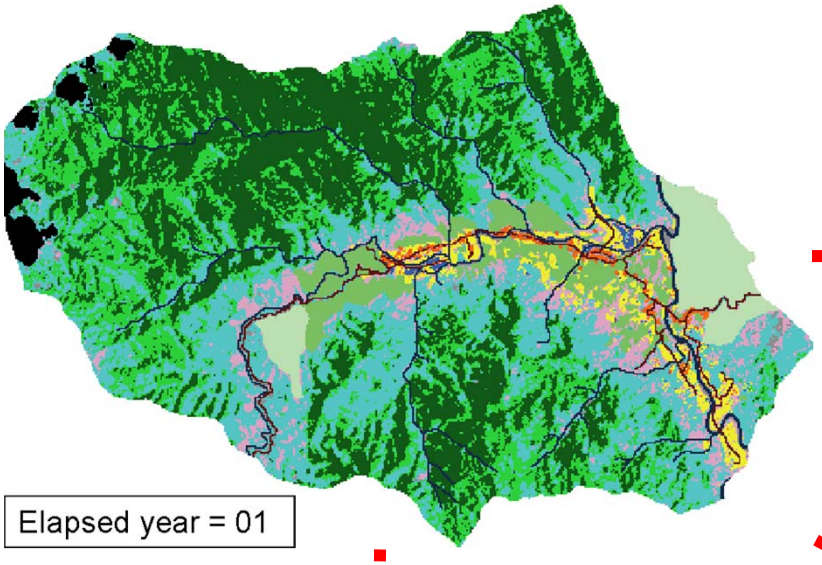
- Construct validity (assumptions, underlying theories): Expert opinions
- Internal validity (elementary relationship used for build model): Inferential statistics
- System behaviour tests: sensitivity and uncertainty analyses
- Relevance: Users' opinions

Forest C-stock, Species Diversity, Soil Erosion

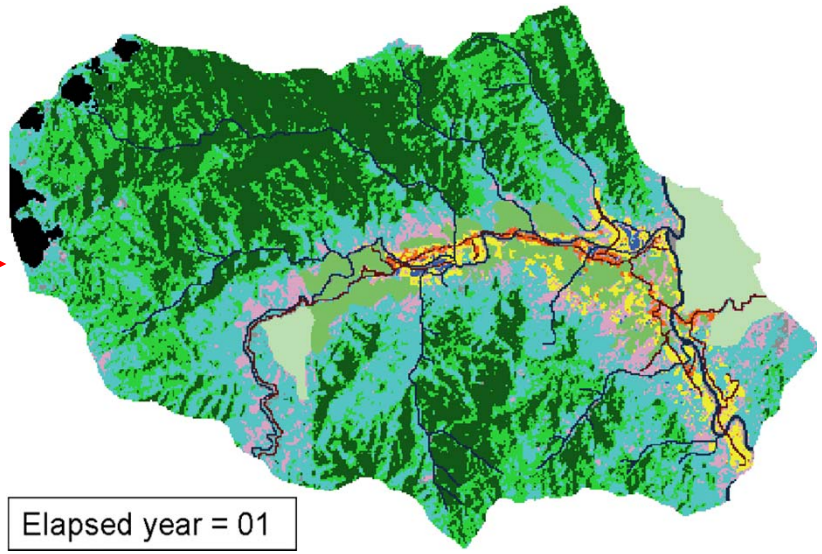
- Forest C-stock, species diversity outputs are still in finalization. Their preliminary pattern (***not shown here yet***) seems follow the pattern of rich forest cover.
- Soil erosion is dropped as it is found not important (very low magnitude, insensitive to change in experimental drivers)

Likely environmental impacts of changes in protection zoning

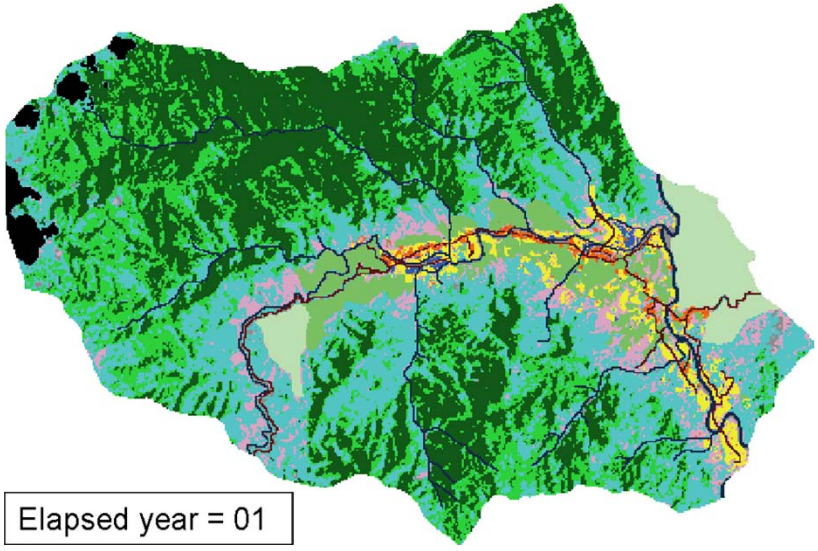
Initial status



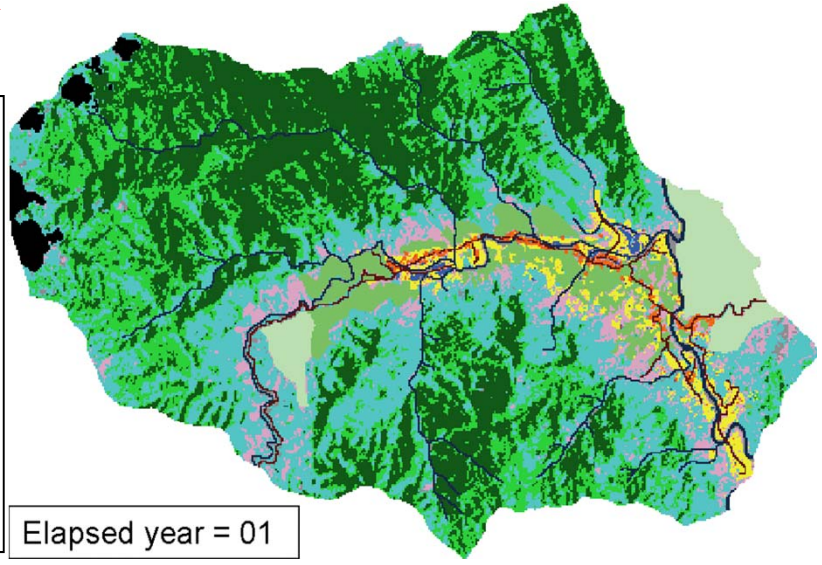
„No Protection“ scenario



„Strict protection“ scenario

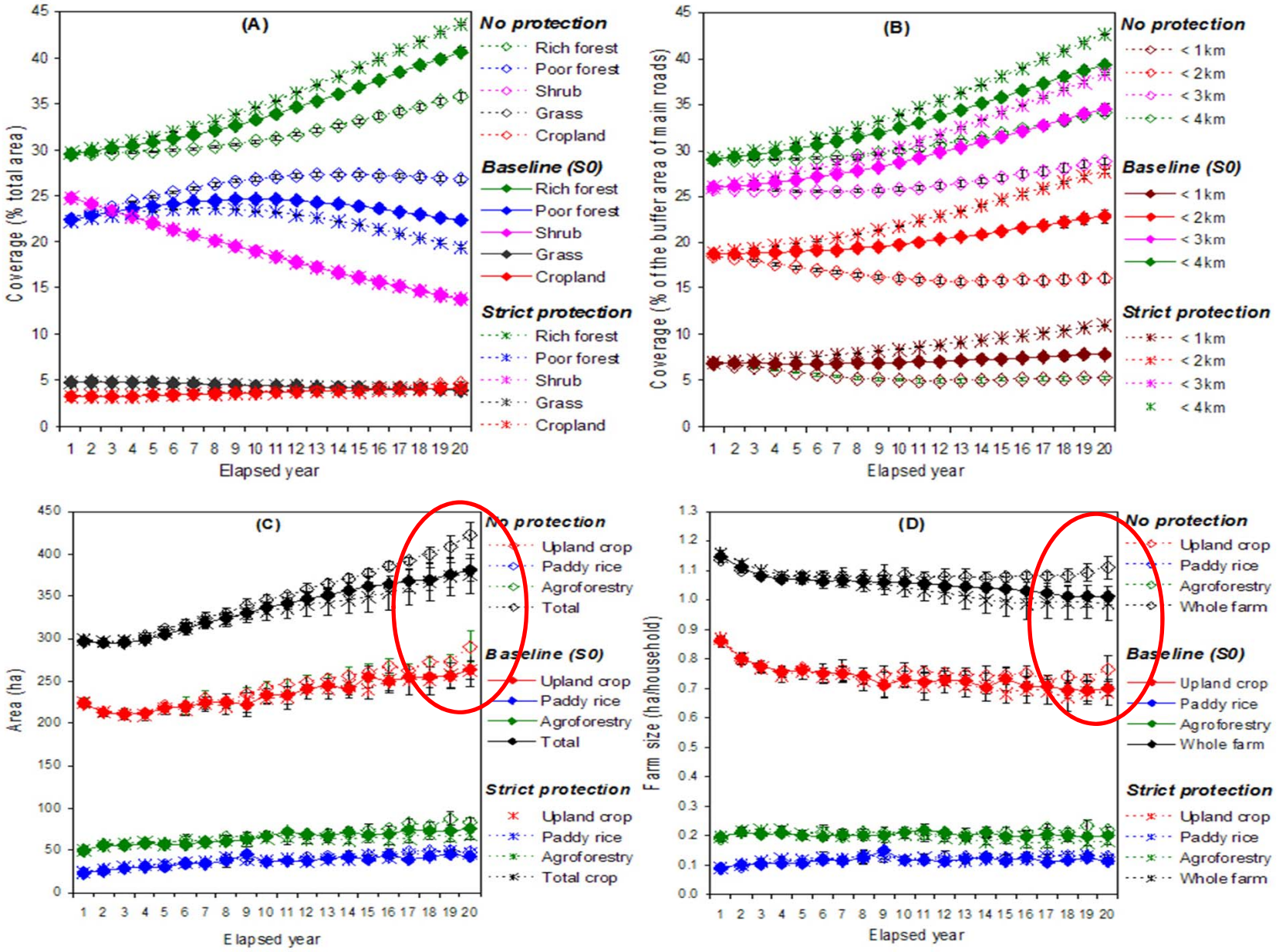


Baseline (status quo) trend



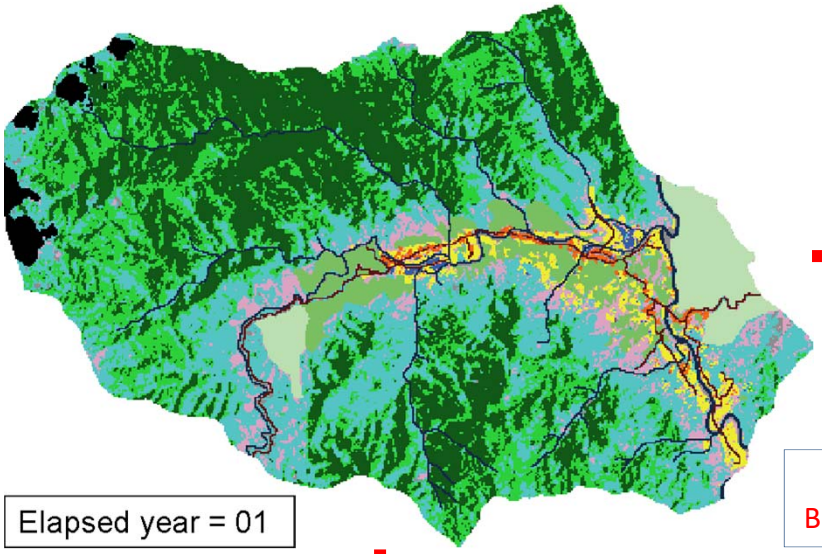
Legend:
- Road
- River/stream
- Upland crop
- Paddy rice
- Agroforestry
- Shrub land
- Grass land
- Young plantation
- Forest plantation
- Open natural forest
- Dense natural forest
- Rocky surface
- No data

Likely environmental impacts of changes in protection zoning

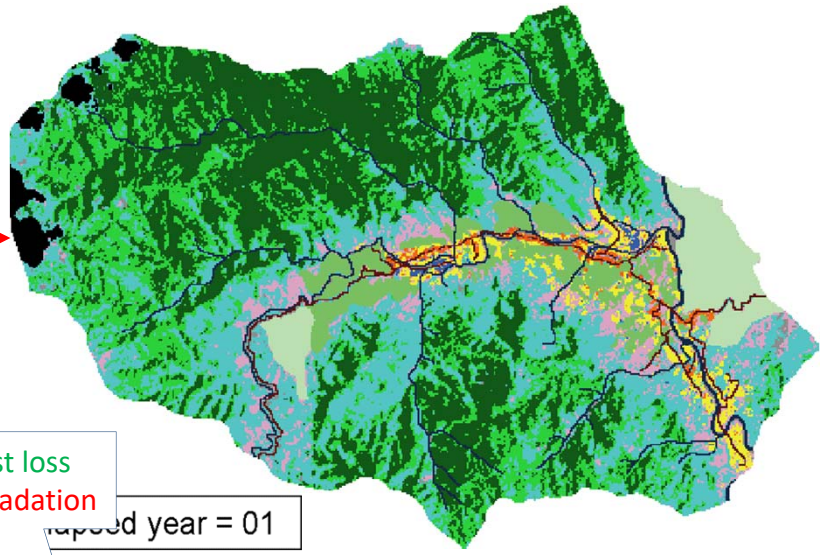


Combined interventions likely increase synegy, reduce trade-offs

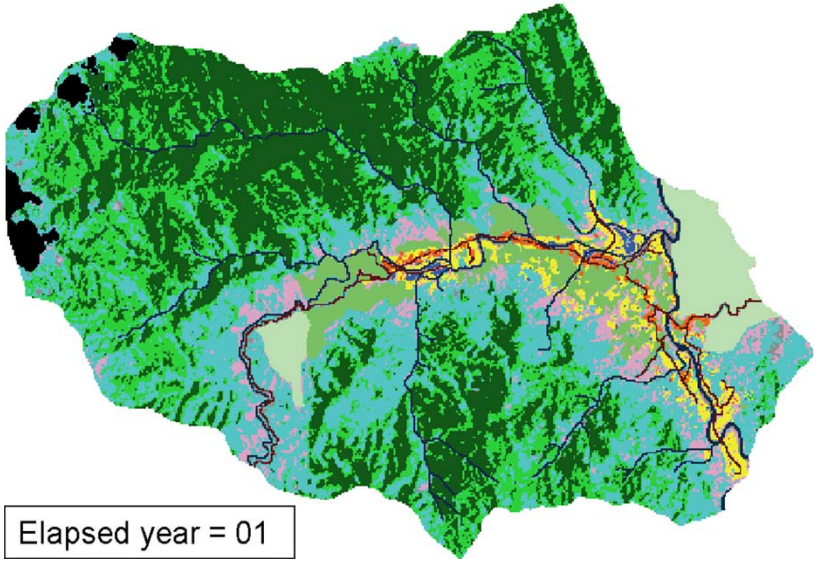
Initial status



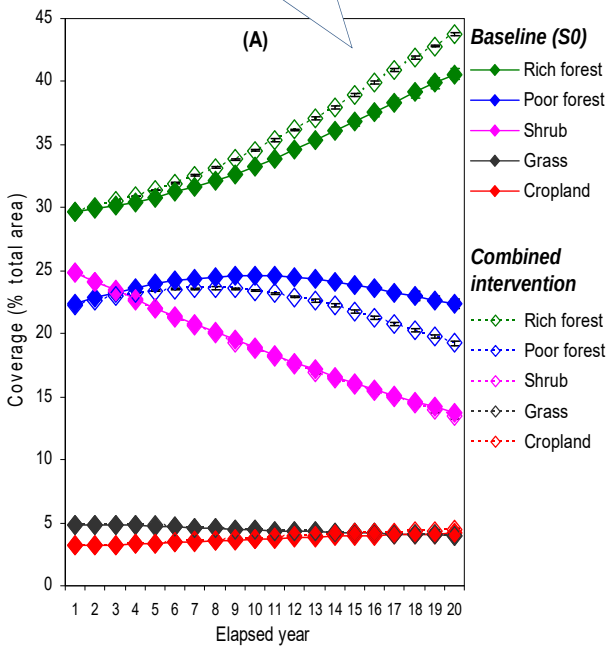
More law enforcement + arg. extension
+ minor fertilizer subsidy, BUT reduced protect area

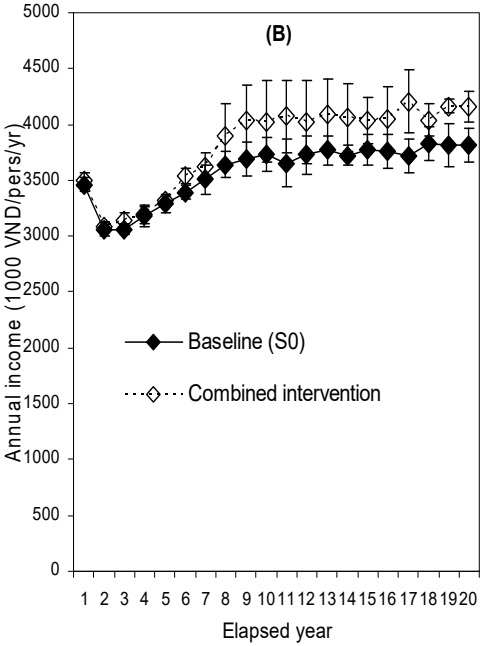


Baseline (status quo) trend

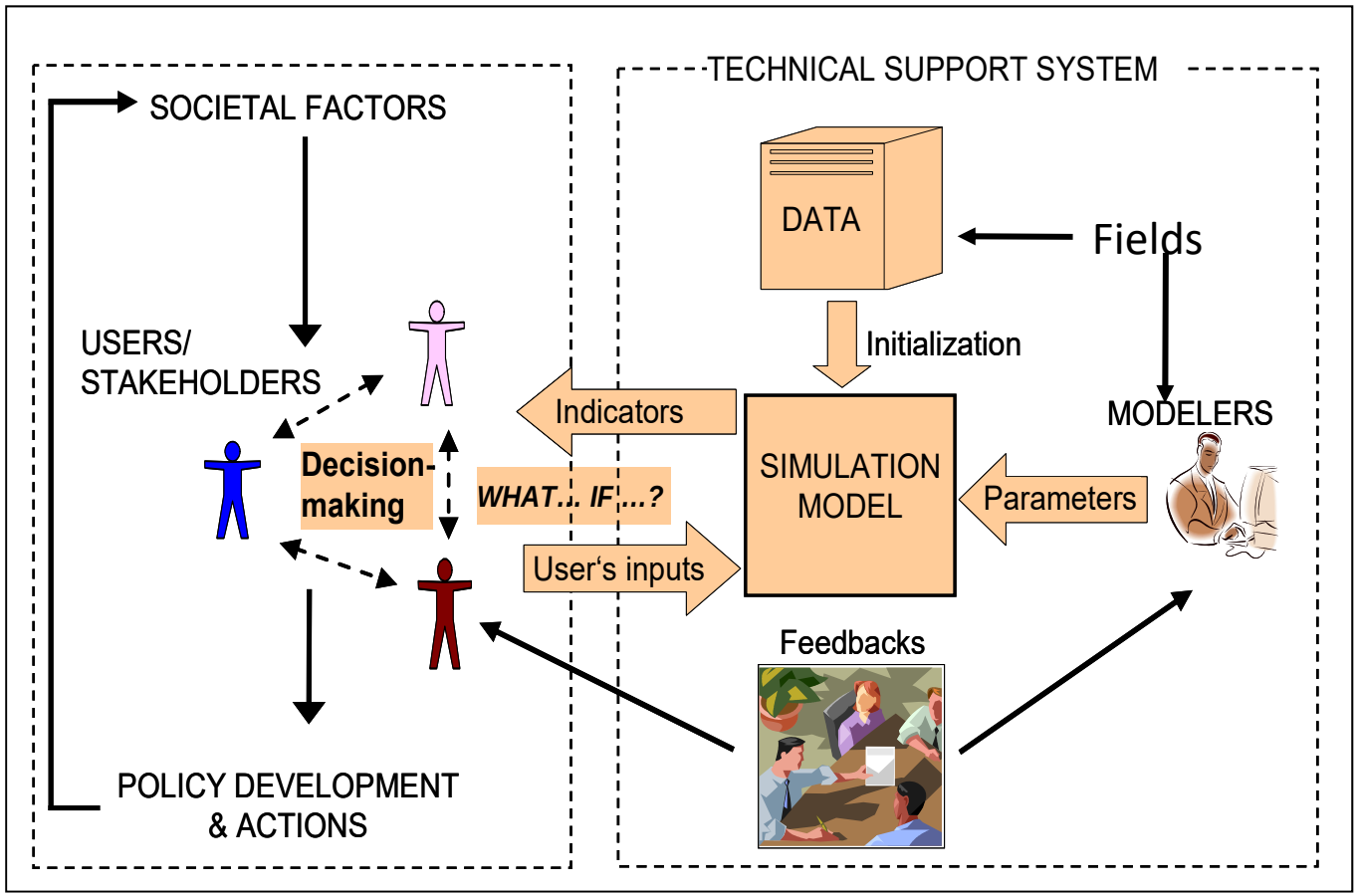


Almost zero net forest loss
But there is forest degradation



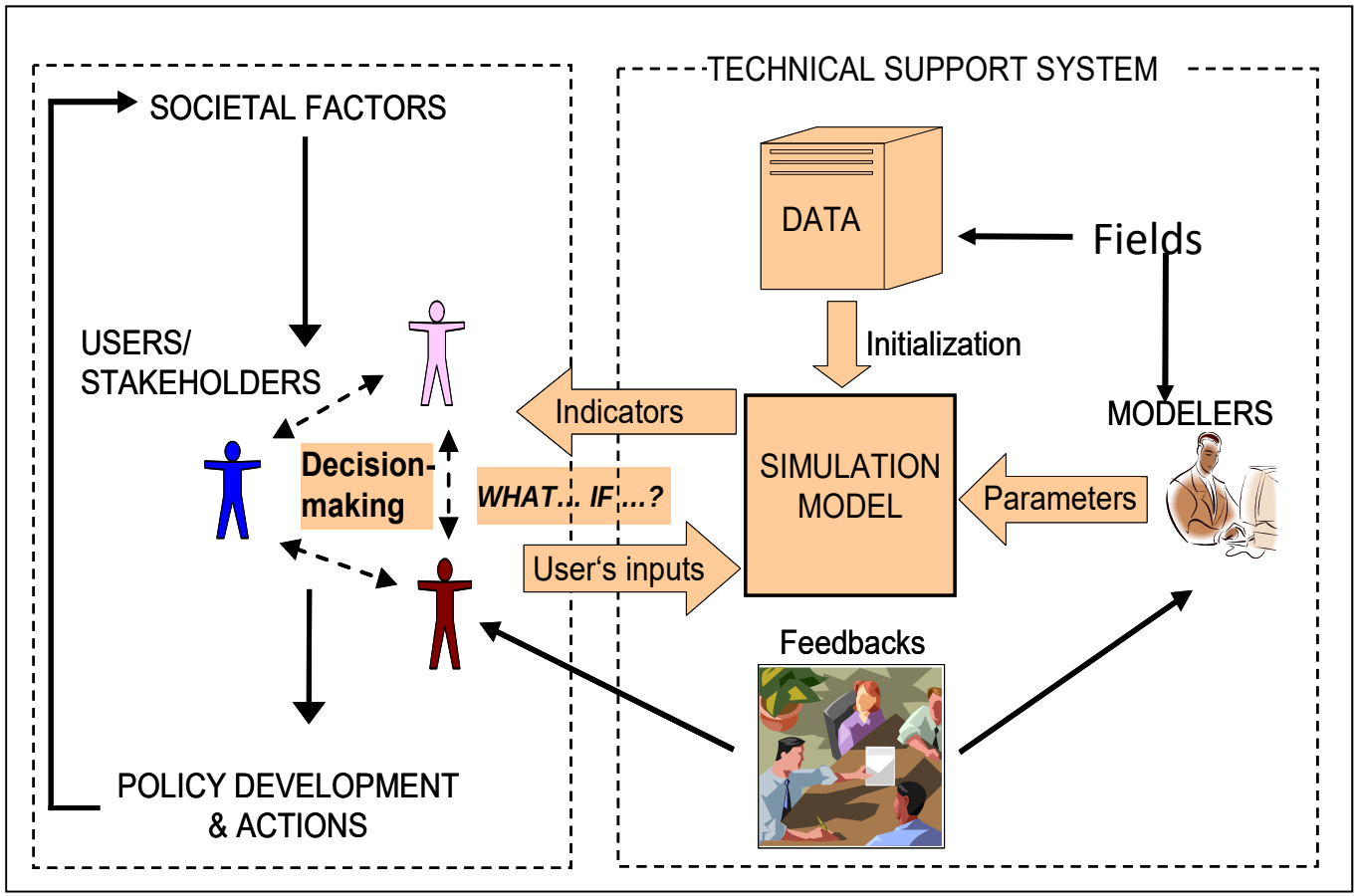


Discussions



- Scientific reasoning driven by the model is just one part of the information needed for actual decision making.
- Model outputs support stakeholders to check assumption/ideas, enhances understanding, and evaluates the consequences of policy actions.
- In the end, human values must be applied on a participatory basis to determine what is a "*good*" policy for a given community on a specific issue.

Discussions



- Trade-off analysis can be done a participatory manner
  - Participatory Multi-Criteria Assessment (pMCA) given model outputs is recommended as a follow-up.