BASQUE CENTRE FOR CLIMATE CHANGE
Klima Aldaketa Ikergai

ARIES
ARtificial Intelligence for Ecosystem Services

Modelling Ecosystem Services Flows from Nature to Humans

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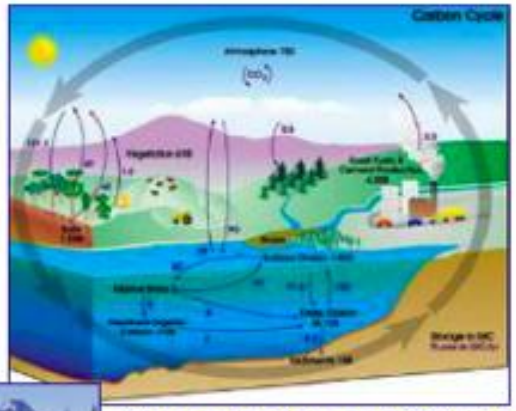
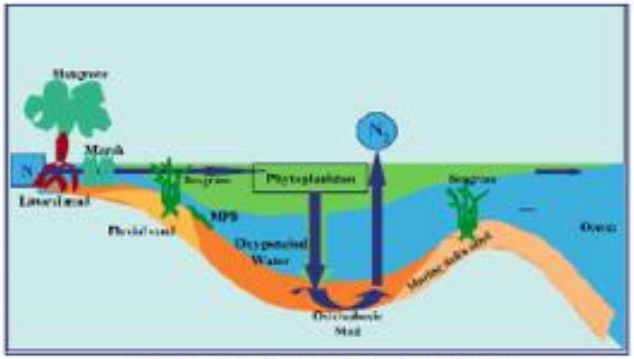


Atmospheric and Climate Regulation

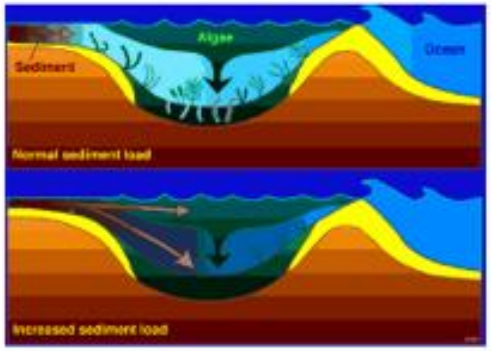
Flood Attenuation/ Storm Surge Protection



Biogeochemical Cycling

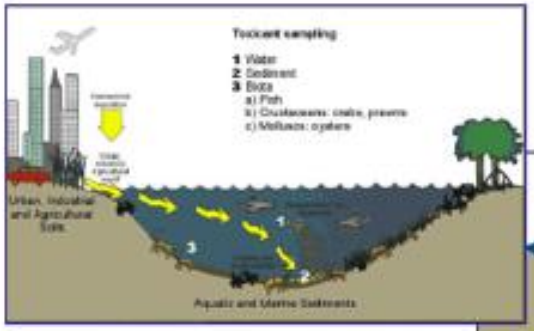
Recreation / Aesthetic

Food and Fiber



Soil and Sediment Regulation

Water Quality and Supply



Waste Regulation

Habitat/Fisheries

Pest and Disease Regulation

Ecosystem Services

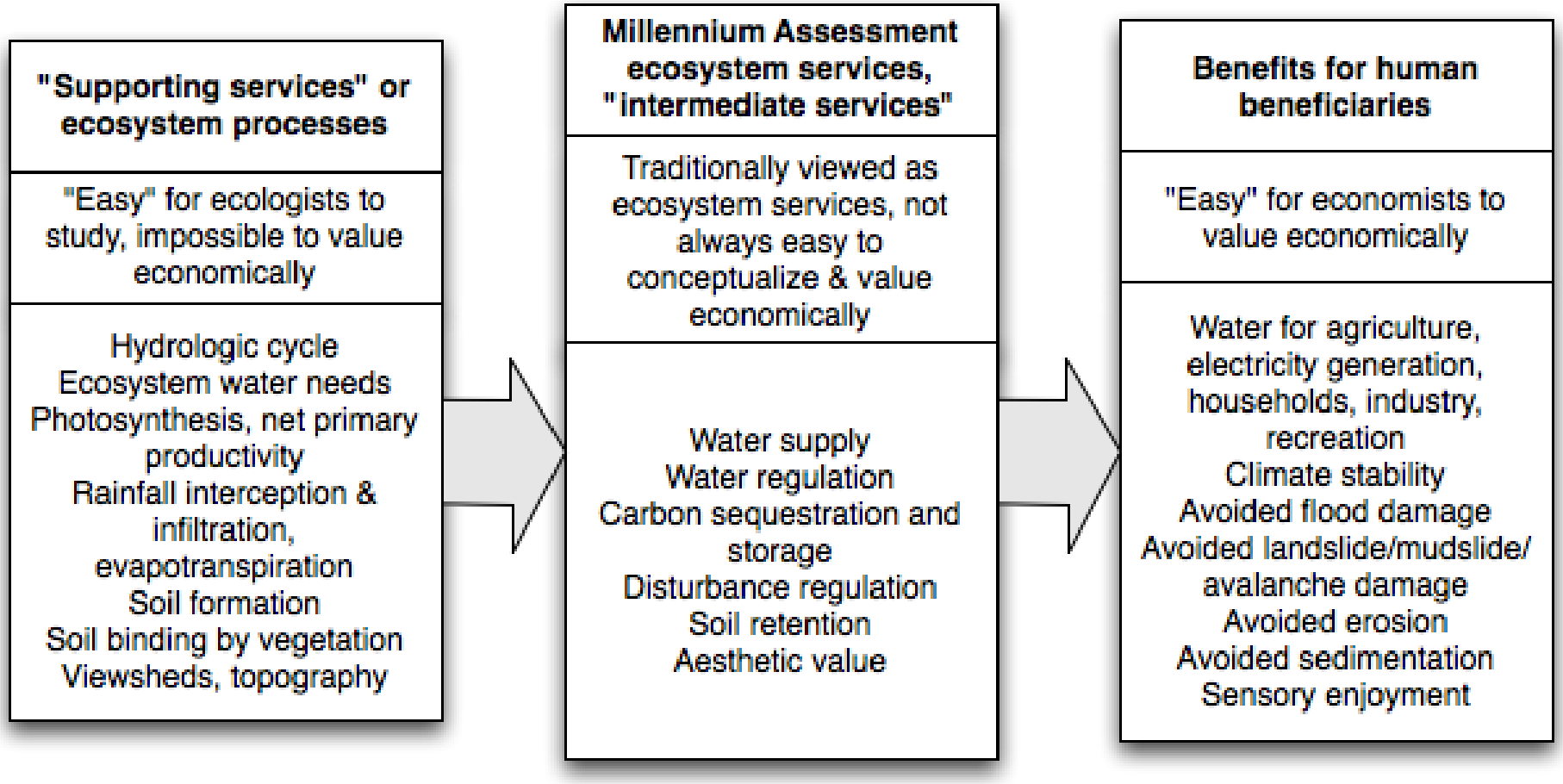
ECOSYSTEM SERVICES in the MILLENNIUM ASSESSMENT

Optimal for communication, raising awareness

Supporting services -Nutrient cycling -Net primary production -Pollination & seed dispersal -Hydrologic cycle...	**Regulating services** -Climate regulation -Disturbance regulation -Water regulation -Nutrient regulation...
Provisioning services -Water supply -Food -Raw materials...	**Cultural services** -Recreation -Aesthetic -Spiritual & historic...

Ecosystem Services are a multiple-scale problem where provision and use have different modes and scales, and flow across the landscape in different manners. Quantitative, spatially explicit assessment and valuation require more systematic and less general definitions.

A quantitatively based framework for ES



ARIES in a nutshell

- A rapid assessment toolkit for ecosystem services and their values; not a single model but an intelligent system that customizes models to user goals.
- Demonstrate a mapping process for ecosystem service provision, use, and flow where most ES assessments only looks at provision.
- “Honest” probabilistic models inform decision-makers of likelihood of all possible outcomes; users can explore effects of policy changes and external events.
- Web based, customizable for specific user groups, geographic areas and policy goals; custom tools implement specific “bottom line”

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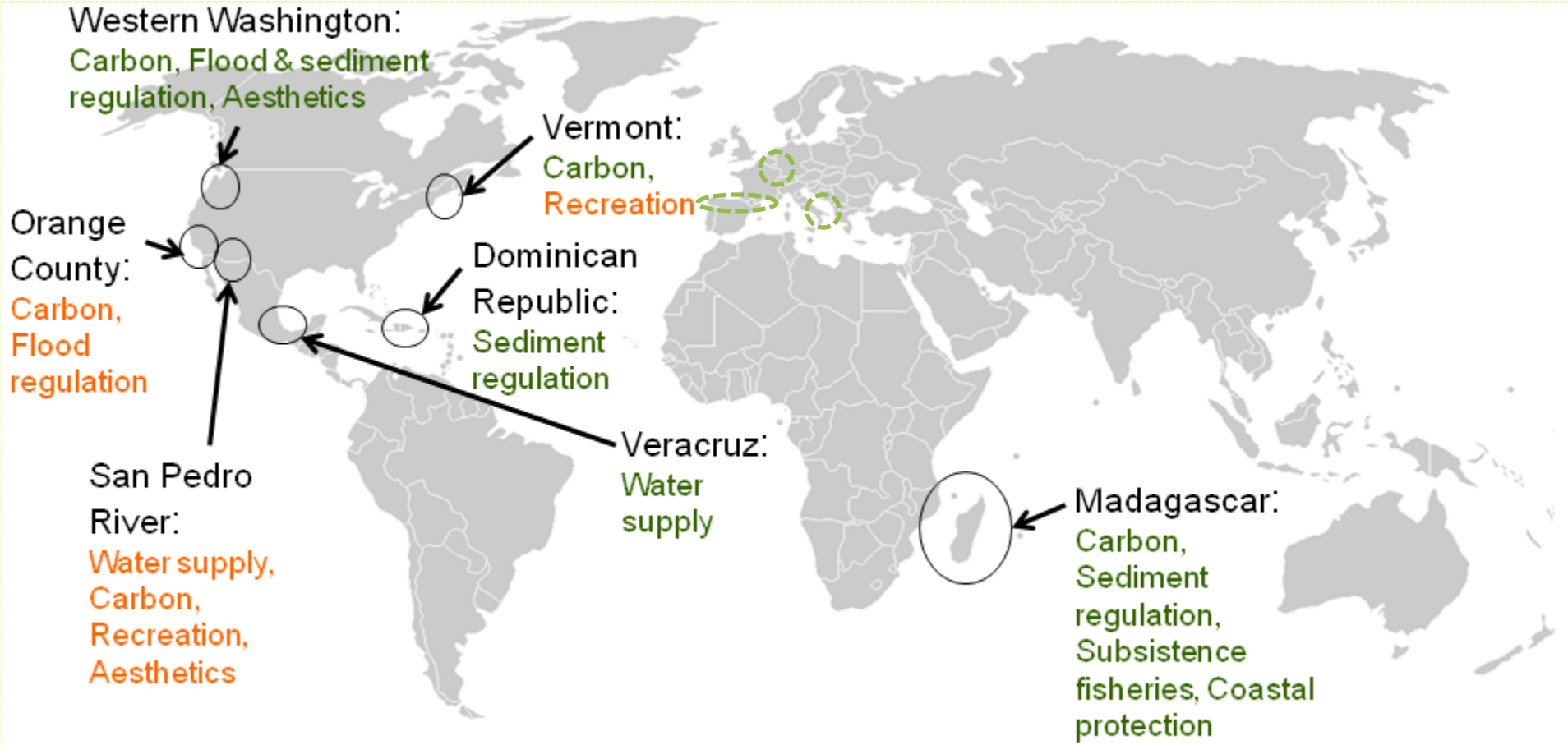
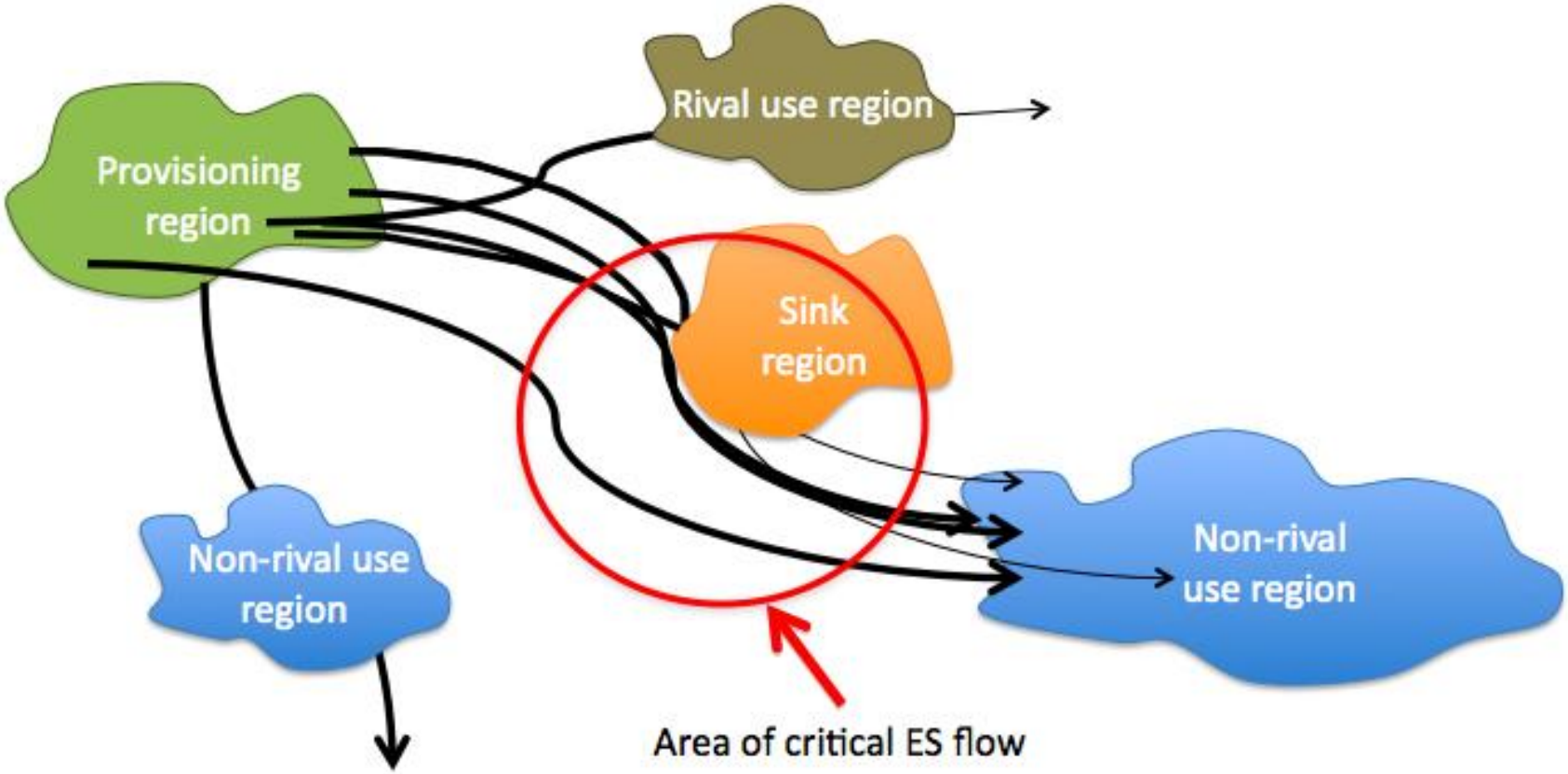
Project details

- Funded by the US National Science Foundation; follows NSF-funded valuation database project
- NSF grant to UVM, CI, EE from ABI program ($927,000); additional funding from UNEP-WCMC, CI. Project lead moved to BC3, Bilbao in 9/2010
- Meant to construct a new web-accessible modeling platform and a set of innovative, spatially explicit and easy to use ESAV models based on new, strong science, targeted to researchers, governmental decision makers and policy makers, corporate ESR offices.

AREAS of APPLICATION so far



Conceptual Ecosystem Service framework

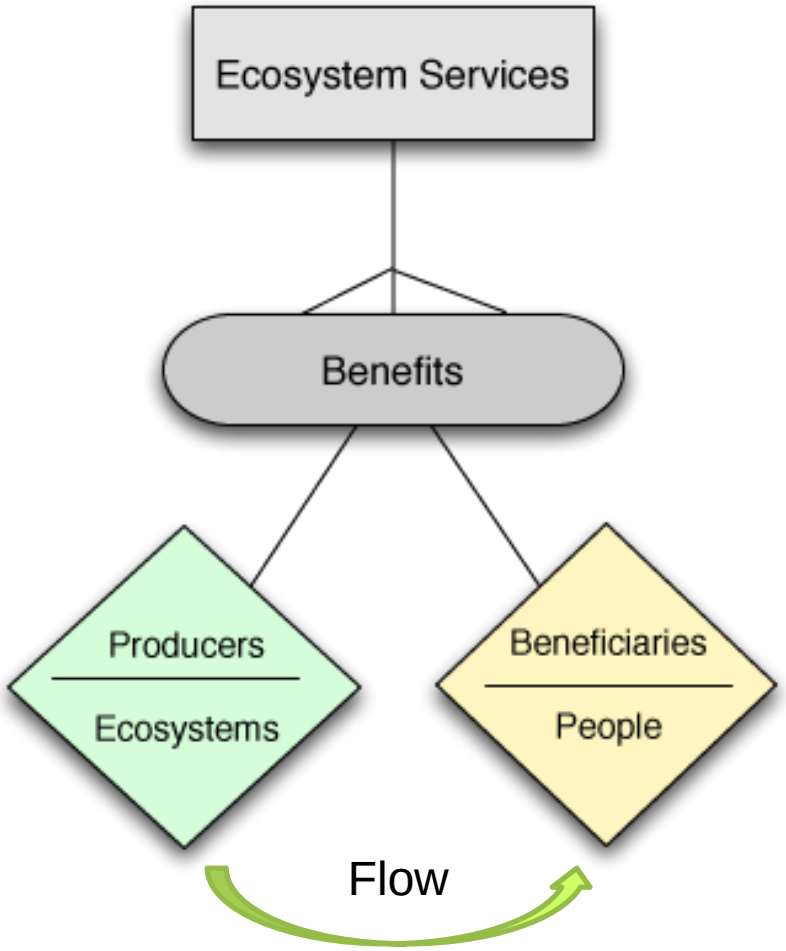


ECOSYSTEM SERVICES in ARIES

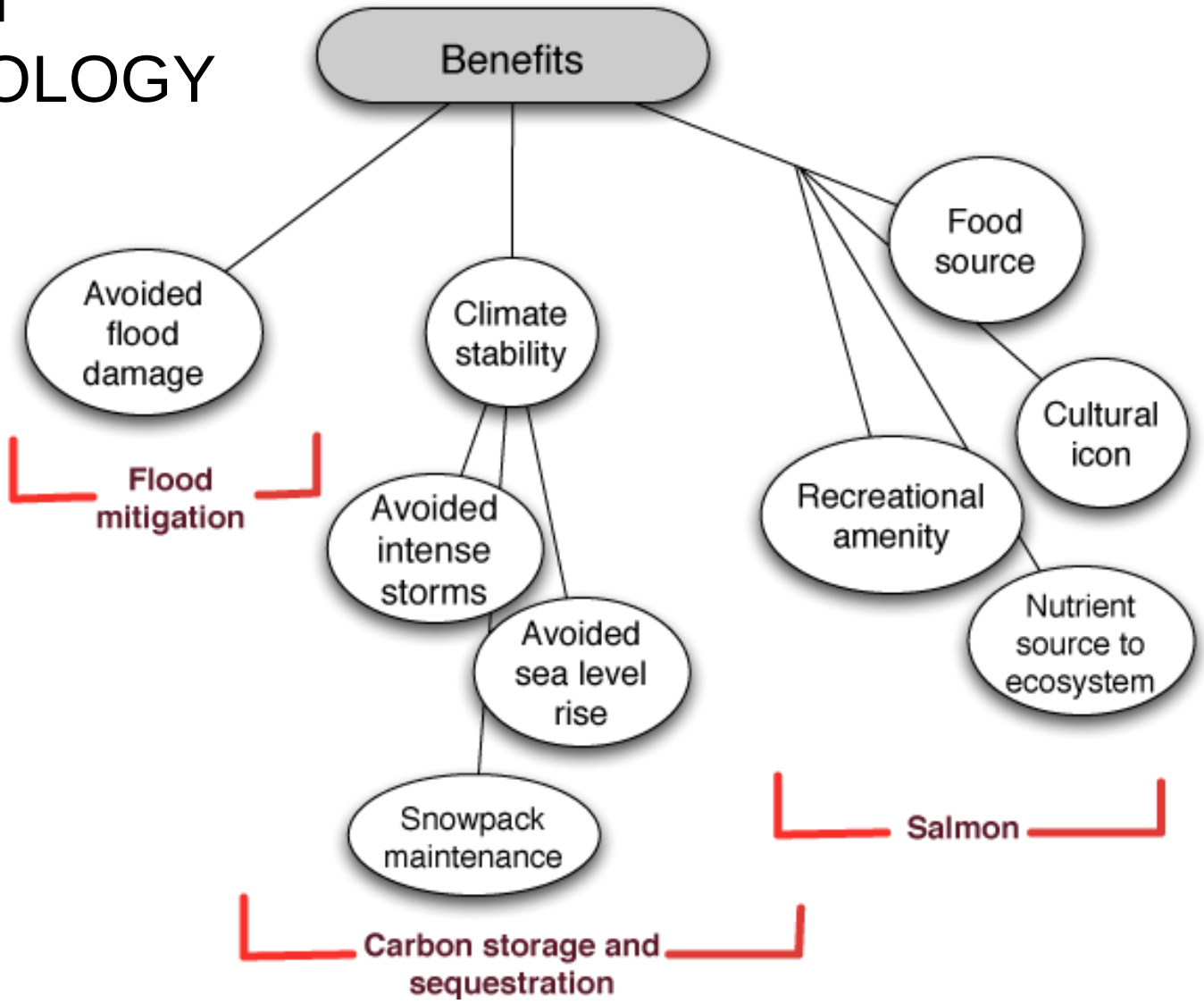
Benefit-oriented, optimal for quantification, modeling and spatial mapping

Ecosystem Services:

the effects on human well-being of the flow of benefits from an ecosystem endpoint to a human endpoint at given extents of space and time



EXAMPLE of ARIES ONTOLOGY



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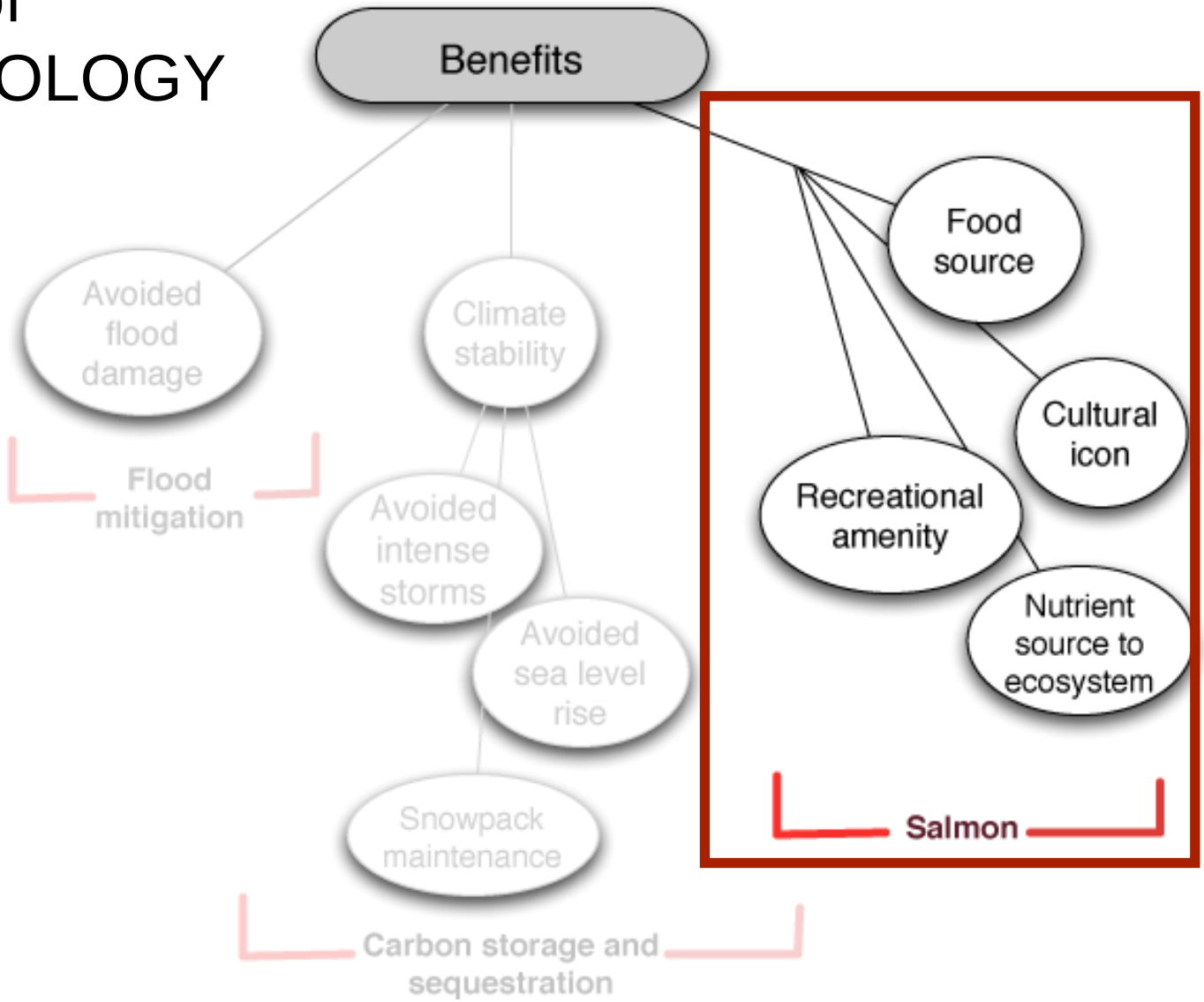

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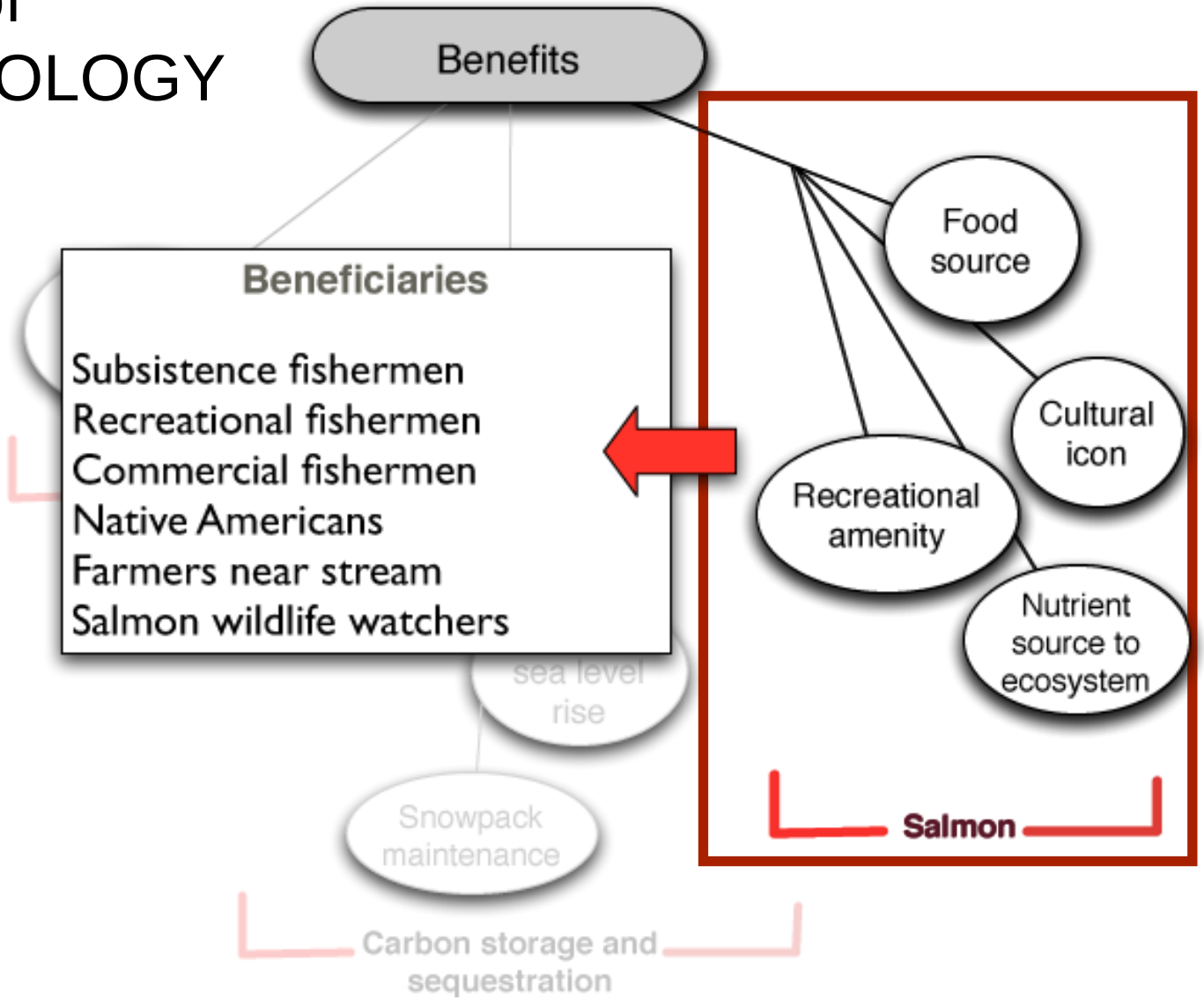

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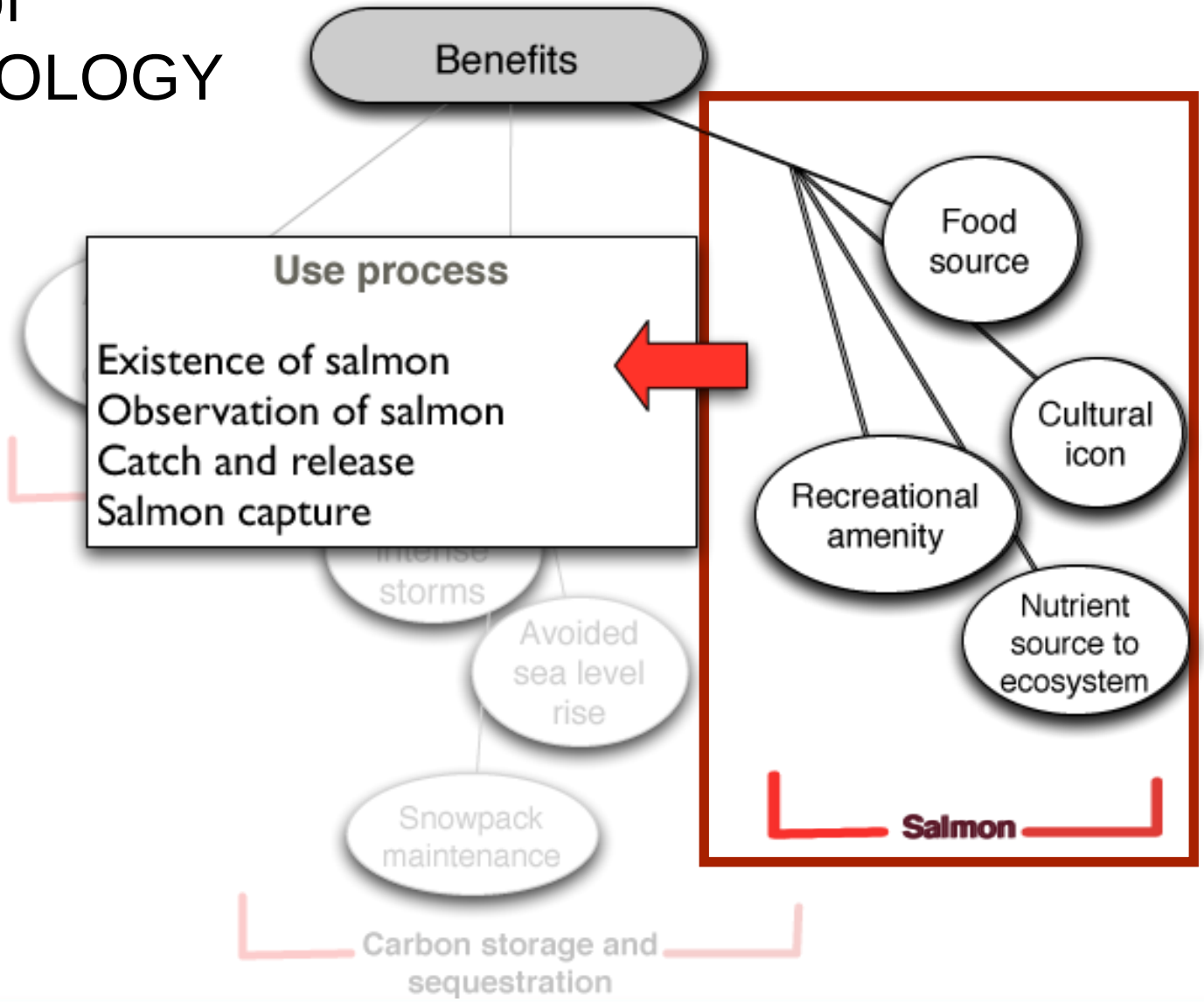
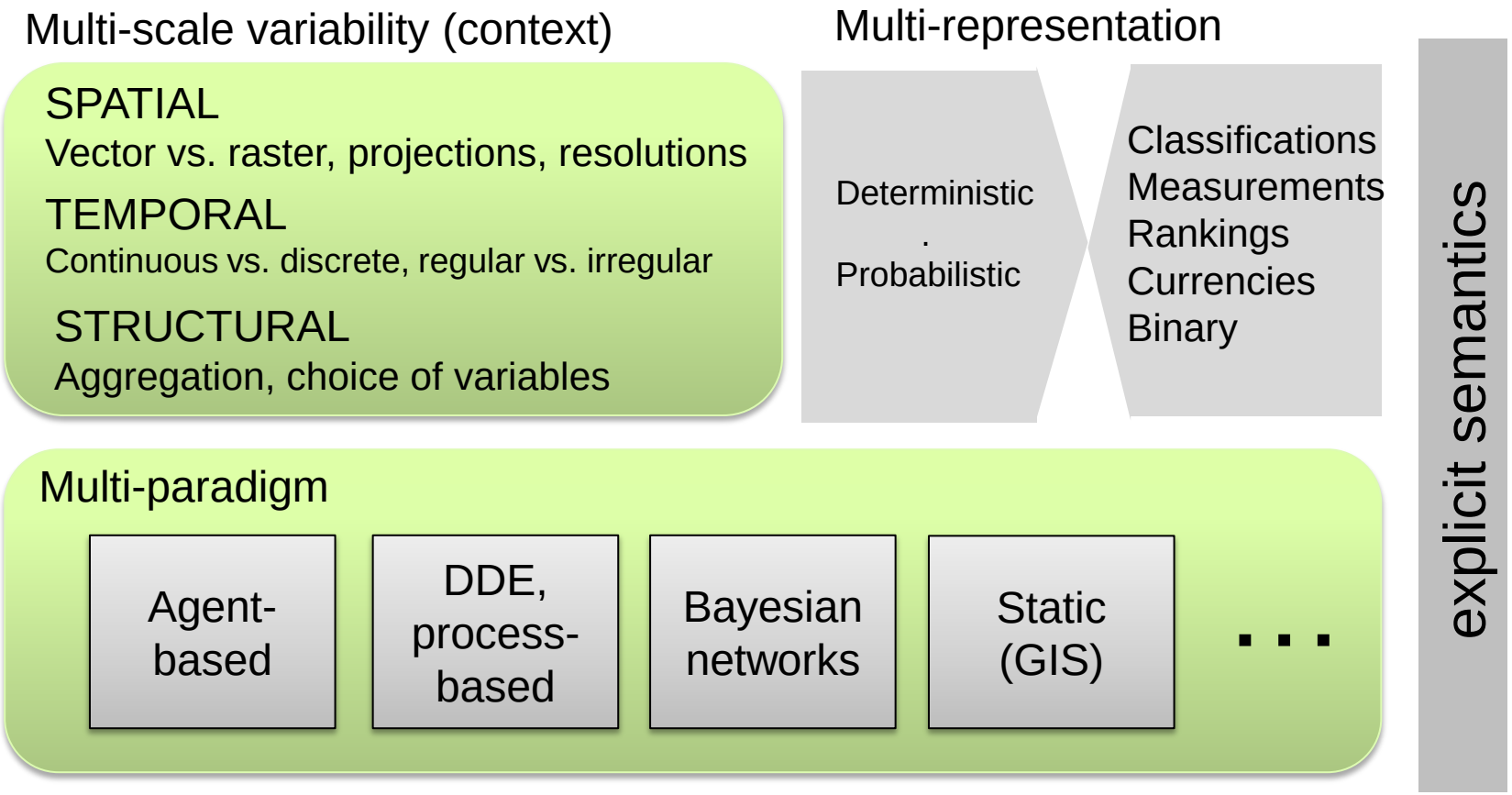
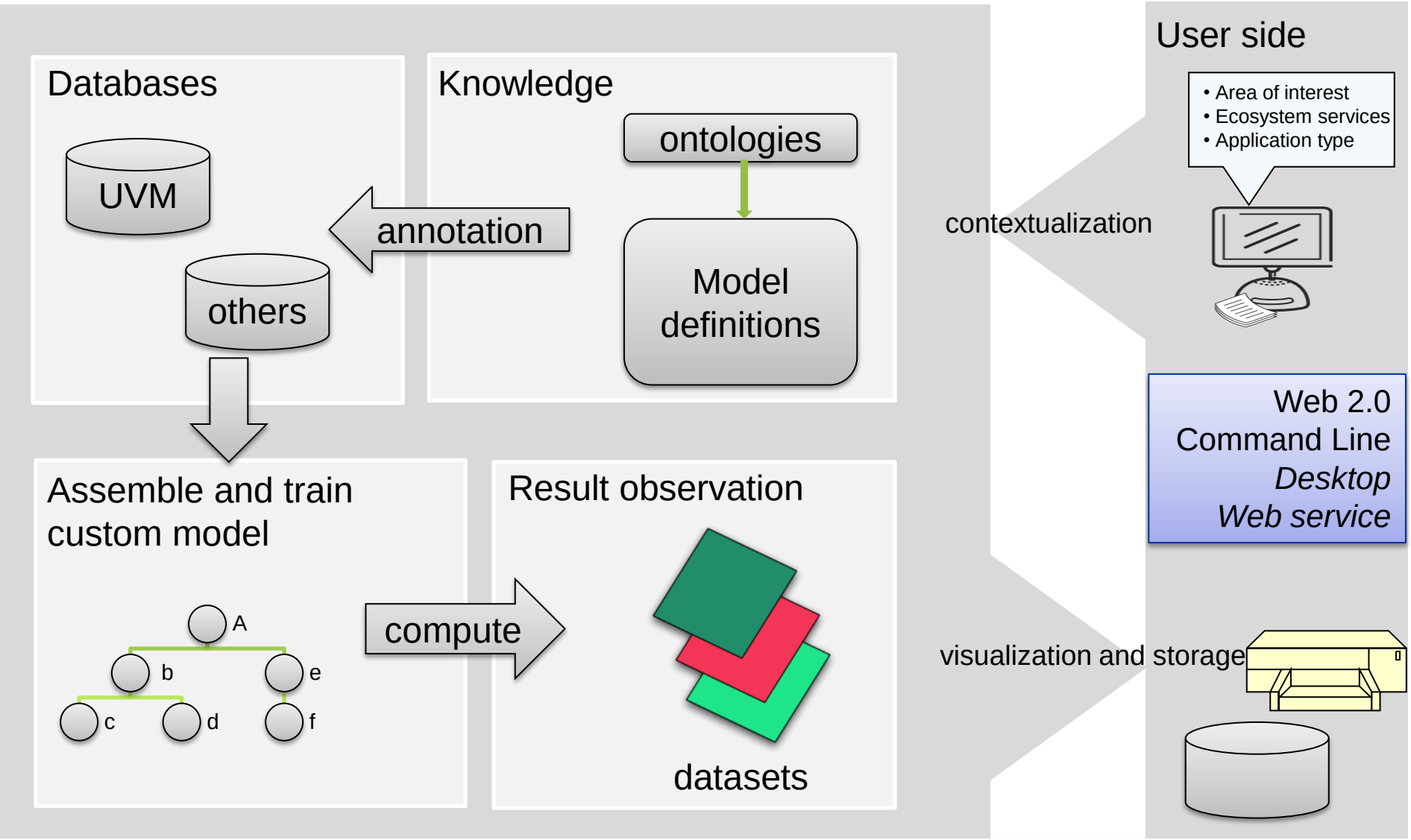


ENABLING TECHNOLOGY: Integrated modeling platform



Semantically annotated data & models -> True Modularity, Substitutability
Content mediation and propagation -> Automatic Scaling & Matching

Session workflow



The three elements of ES modeling in ARIES

1. provisionsheds

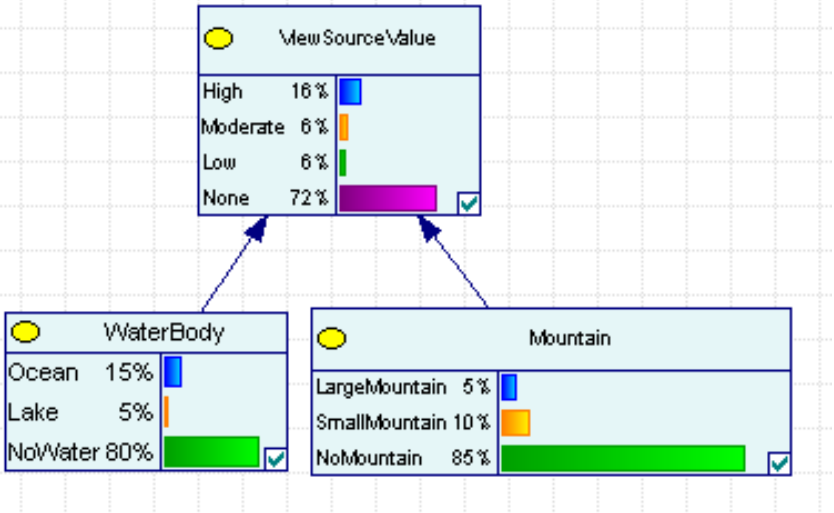
1. Areas of provision of ES and biodiversity

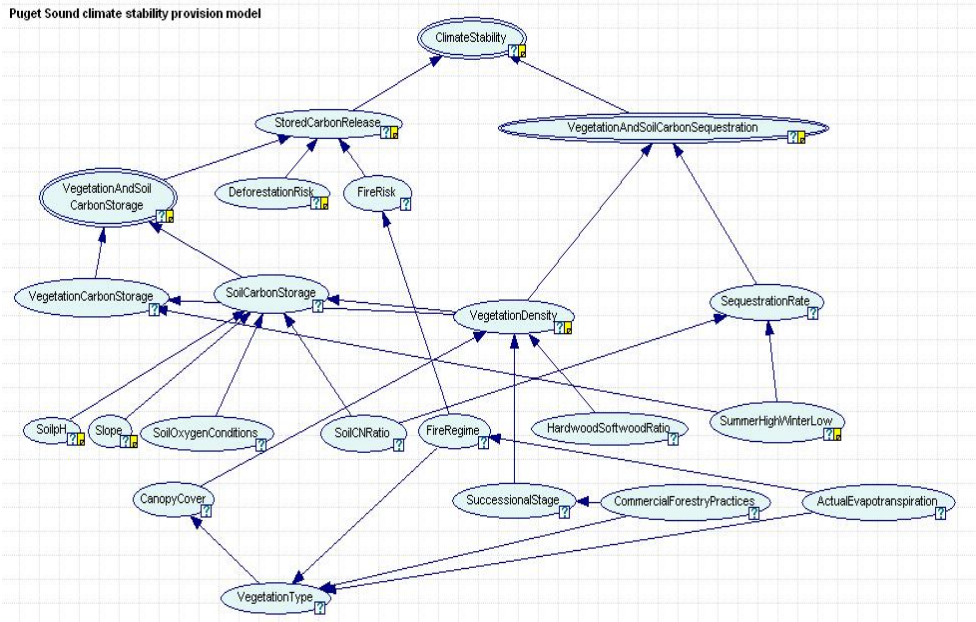
3. Flow paths between areas of provision and areas of use

2. Areas of use of ES and biodiversity where beneficiaries are located

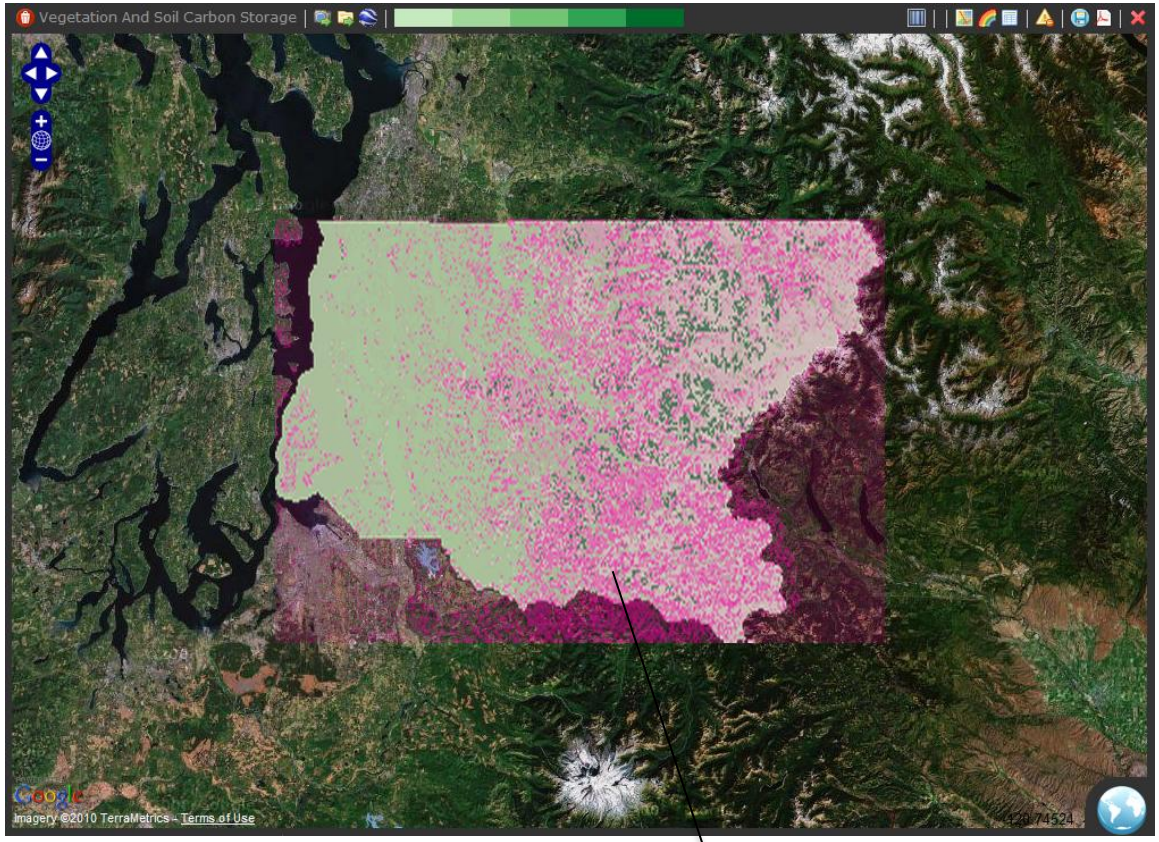
Modeling ES provision

- For entire model or model inputs:
  - Use existing ecological models & their outputs if they exist
  - If no good models exist, build ad hoc models based on expert ecological knowledge
- How much of a given benefit is produced for each landscape district?





“Conventional” ES source mapping



Pink overlay is a visual cue to uncertainty

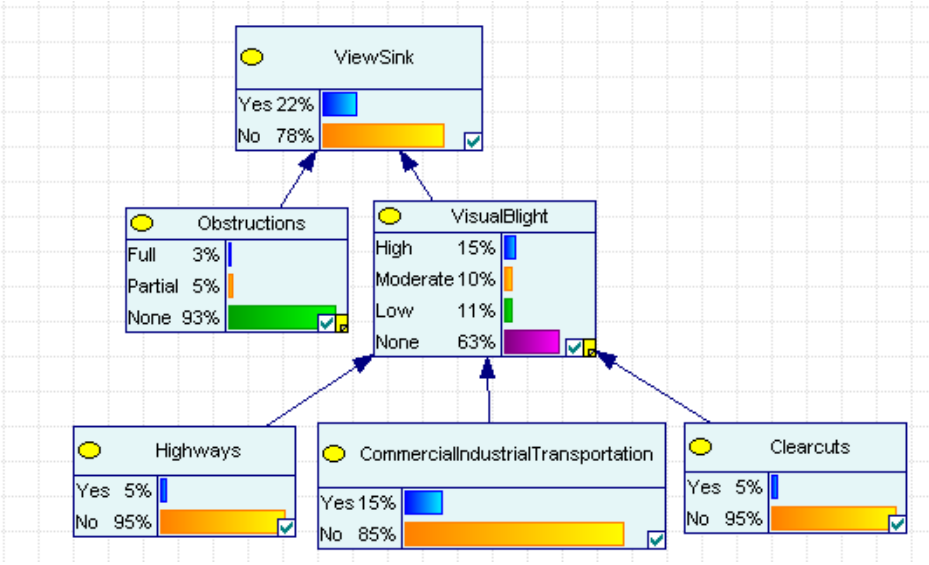
Source mapping estimates the potential value provided by each ES (tonnes of sequestered C in this image)

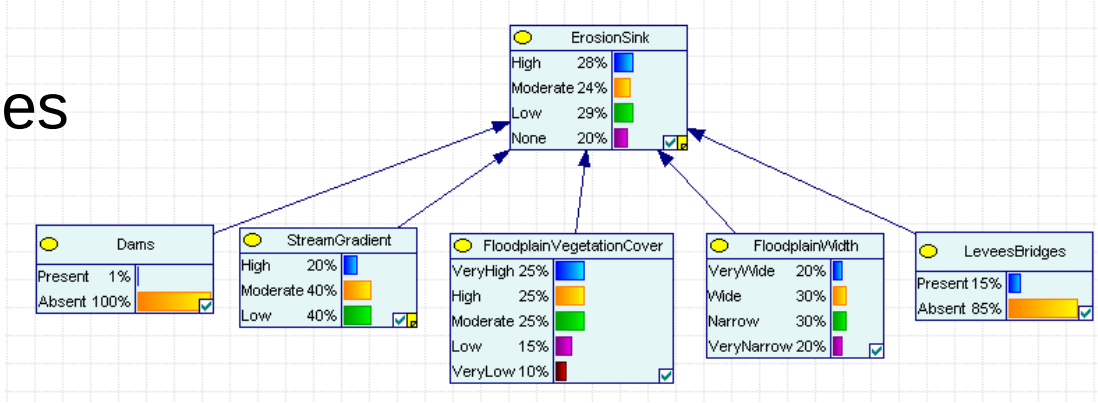
ARIES builds the source models according to the geological, ecological and climate variables describing the areas.

ARIES is the only approach that also estimates in conditions of data scarcity.

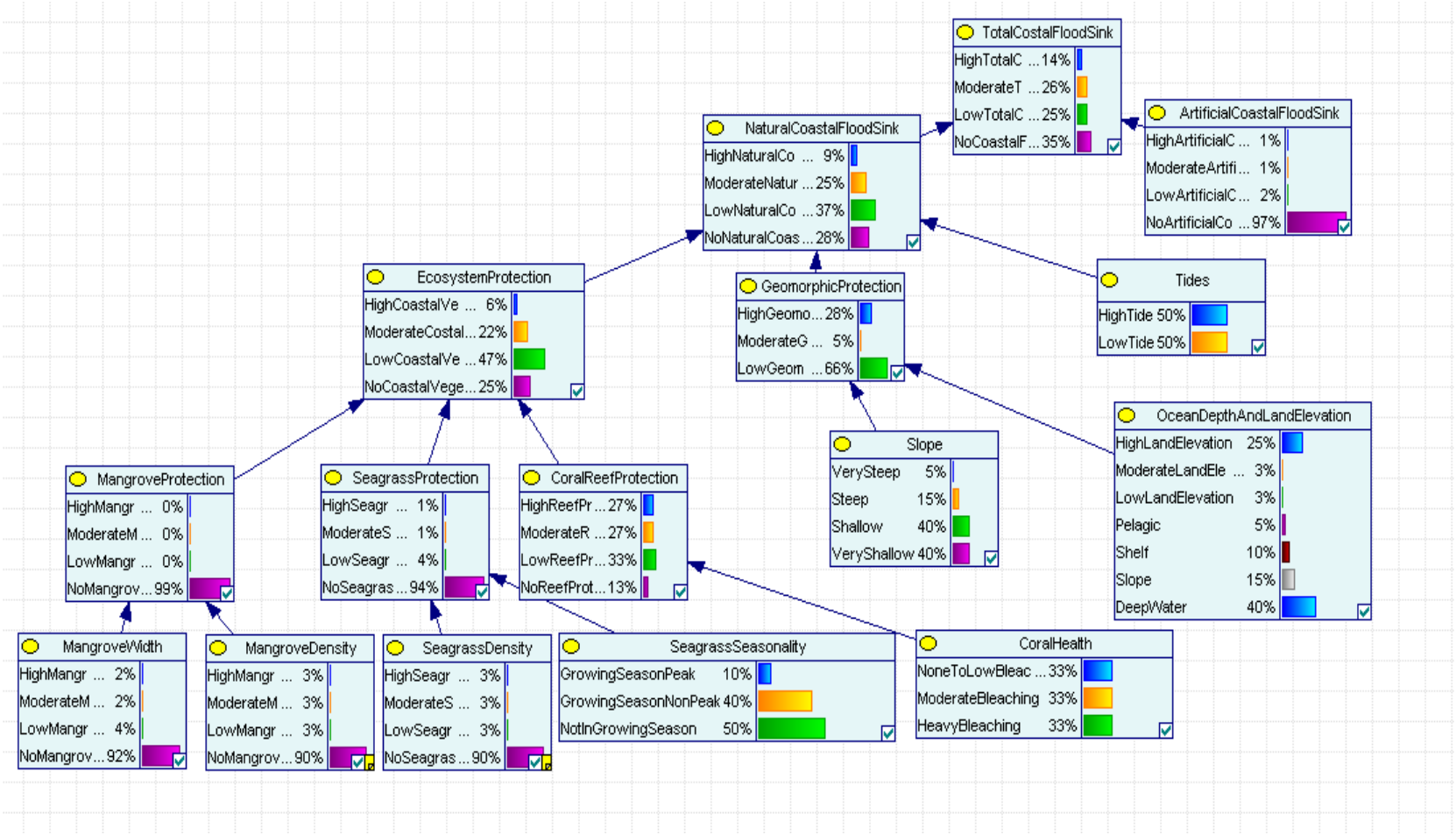
Modeling ES sinks

- Depending on the service, sinks could provide a benefit:
  - Absorption of flood water, nutrients
- Or a be a detriment:
  - Visual blight reducing the quality of views
  - Dampening out of values over distance



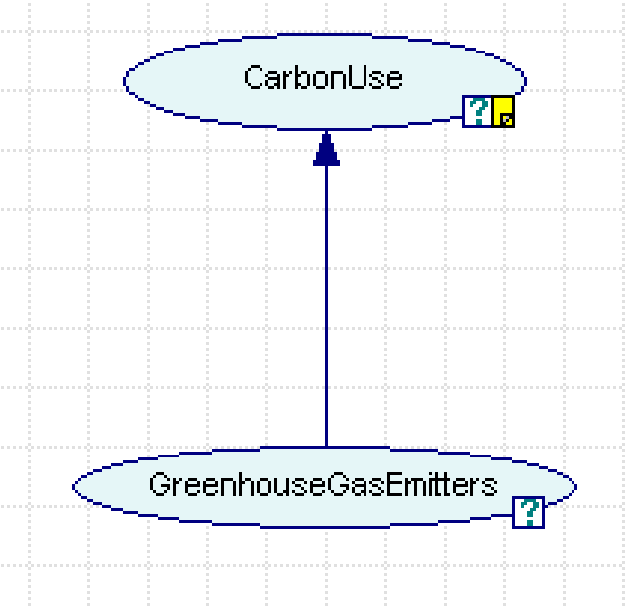


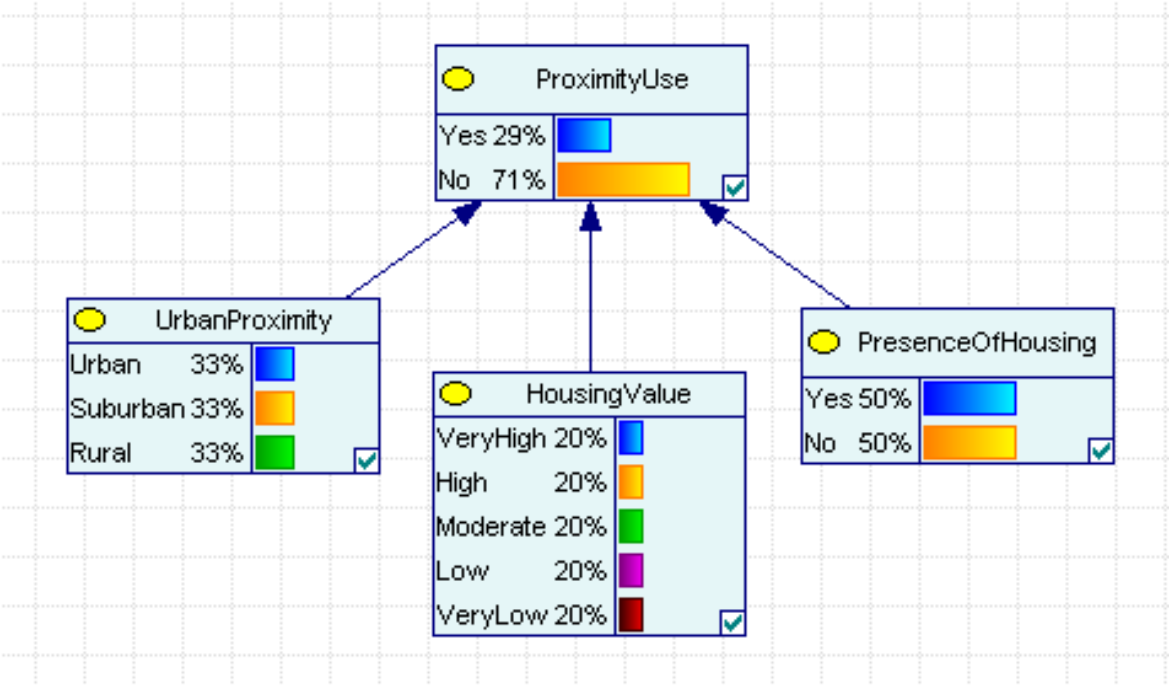
Example: wave sink model (coastal protection MG)



Modeling ES use

- Similar process to modeling ES provision
  - How do we locate (potential) users of ES on the landscape and quantify their need?





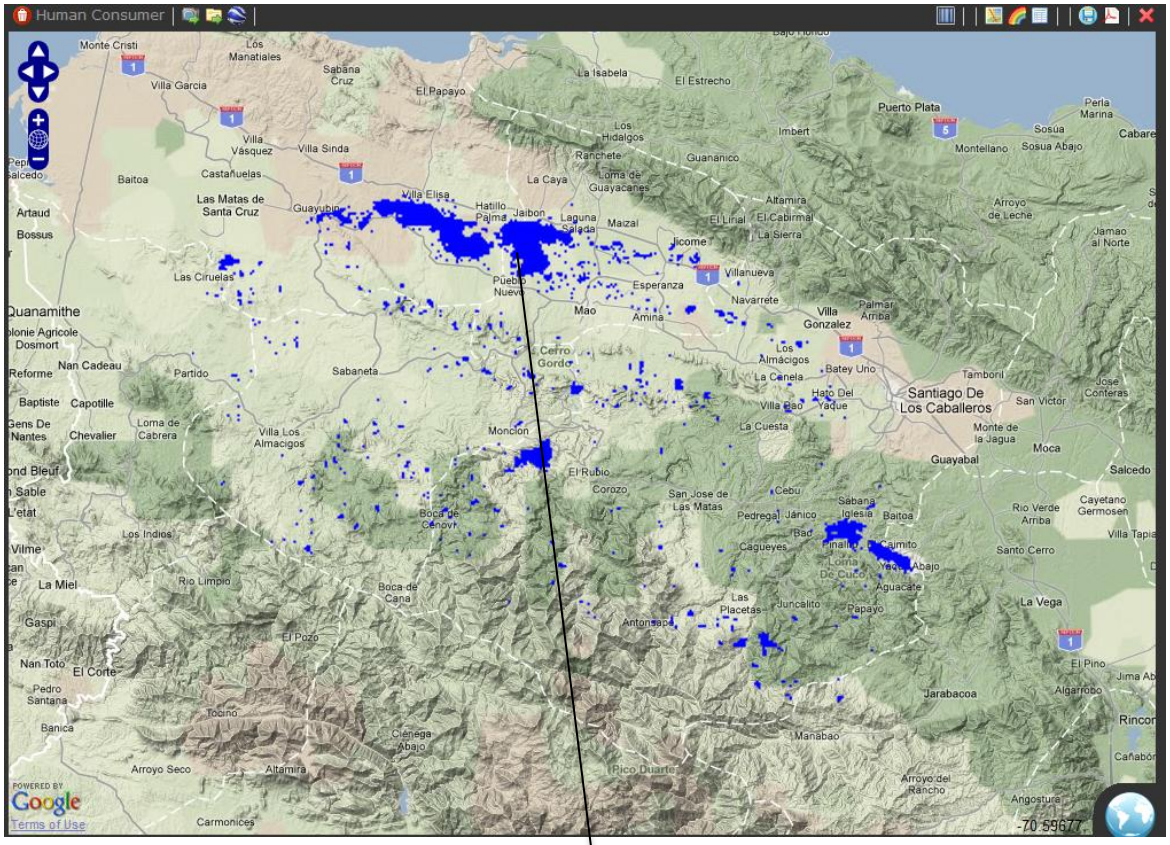
STAKEHOLDER MAPPING

Analysis can be performed for all relevant beneficiary groups

Maps the location and level of need of the potential beneficiaries of each service.

Beneficiary maps can be also made for actual and potential beneficiaries through flow analysis.

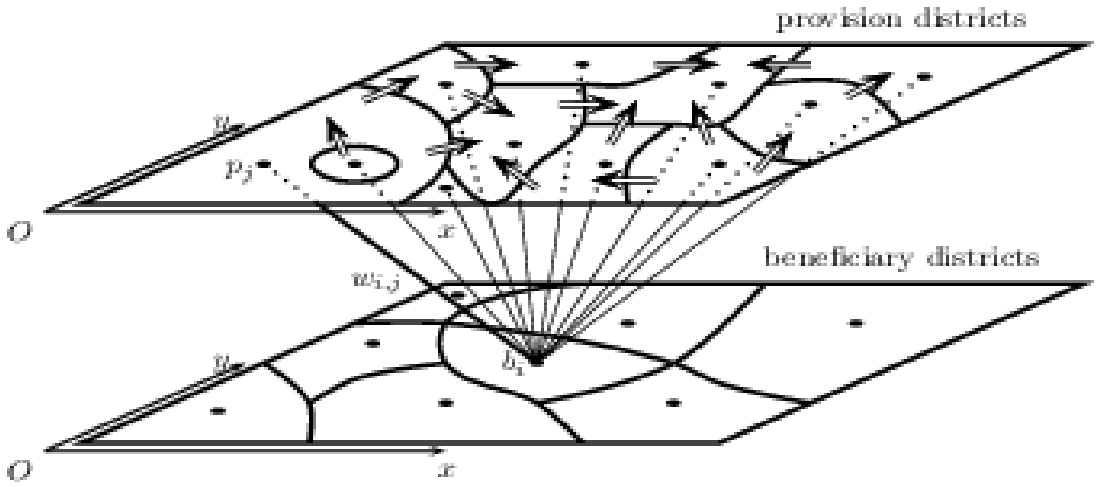
Potential beneficiaries can be the object of planning enhanced flows for positive impact assessment.



Blue overlay represents local farming communities and their dependence on soil deposition/erosion

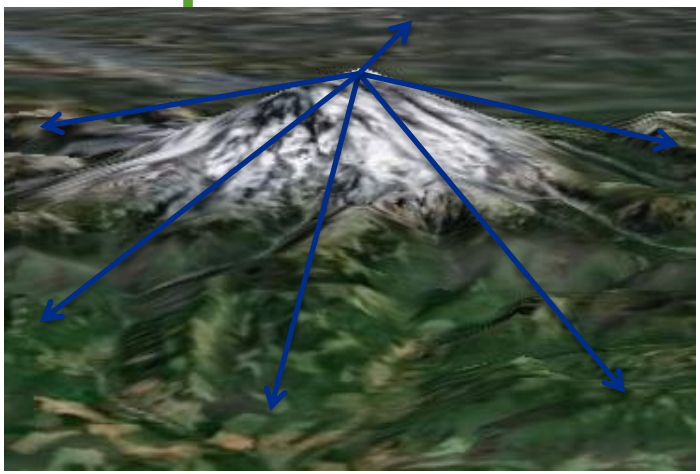
FLOW MAPPING
Source, use and sink are only initial conditions

Service flows will accrue at use locations on the landscape.
Note: Beneficiary regions may be of different scale than provisioning regions



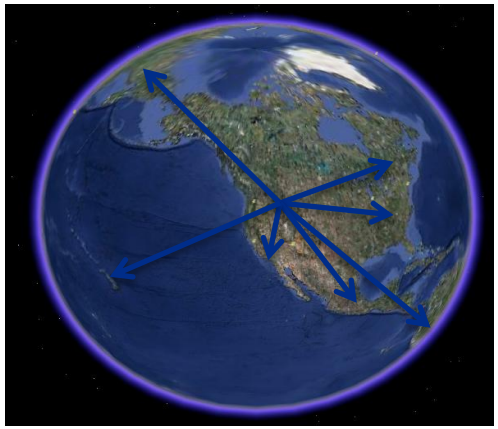
Identifying carriers & flow paths

Hydrologic services



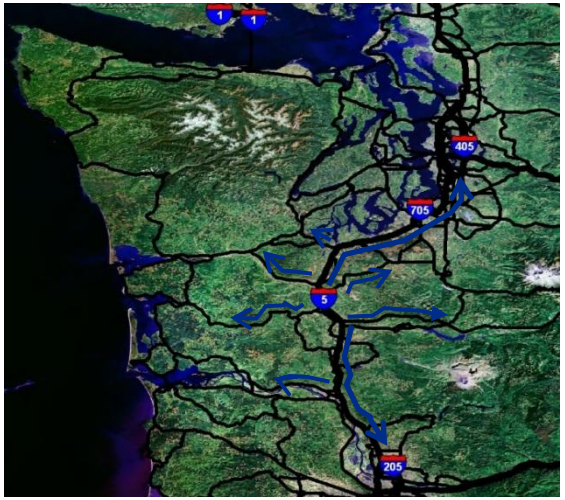
Aesthetic viewsheds

Recreation, flood regulation, many ecosystem goods



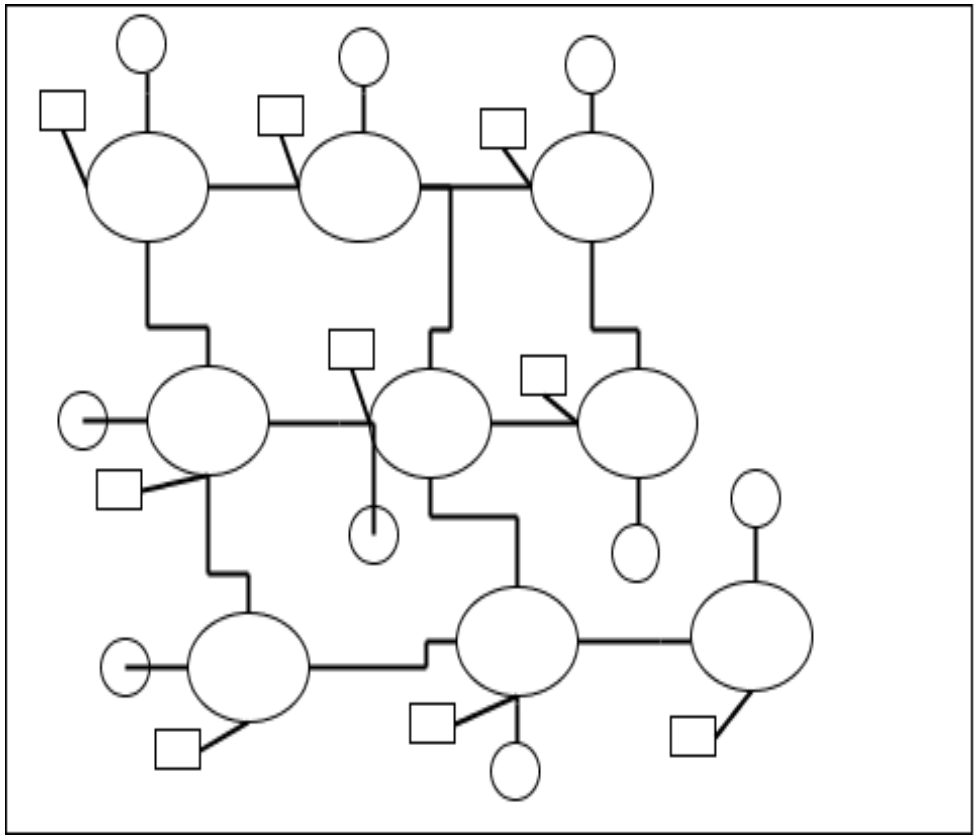
Carbon sequestration, some cultural values

Recreation, aesthetic proximity, some cultural services

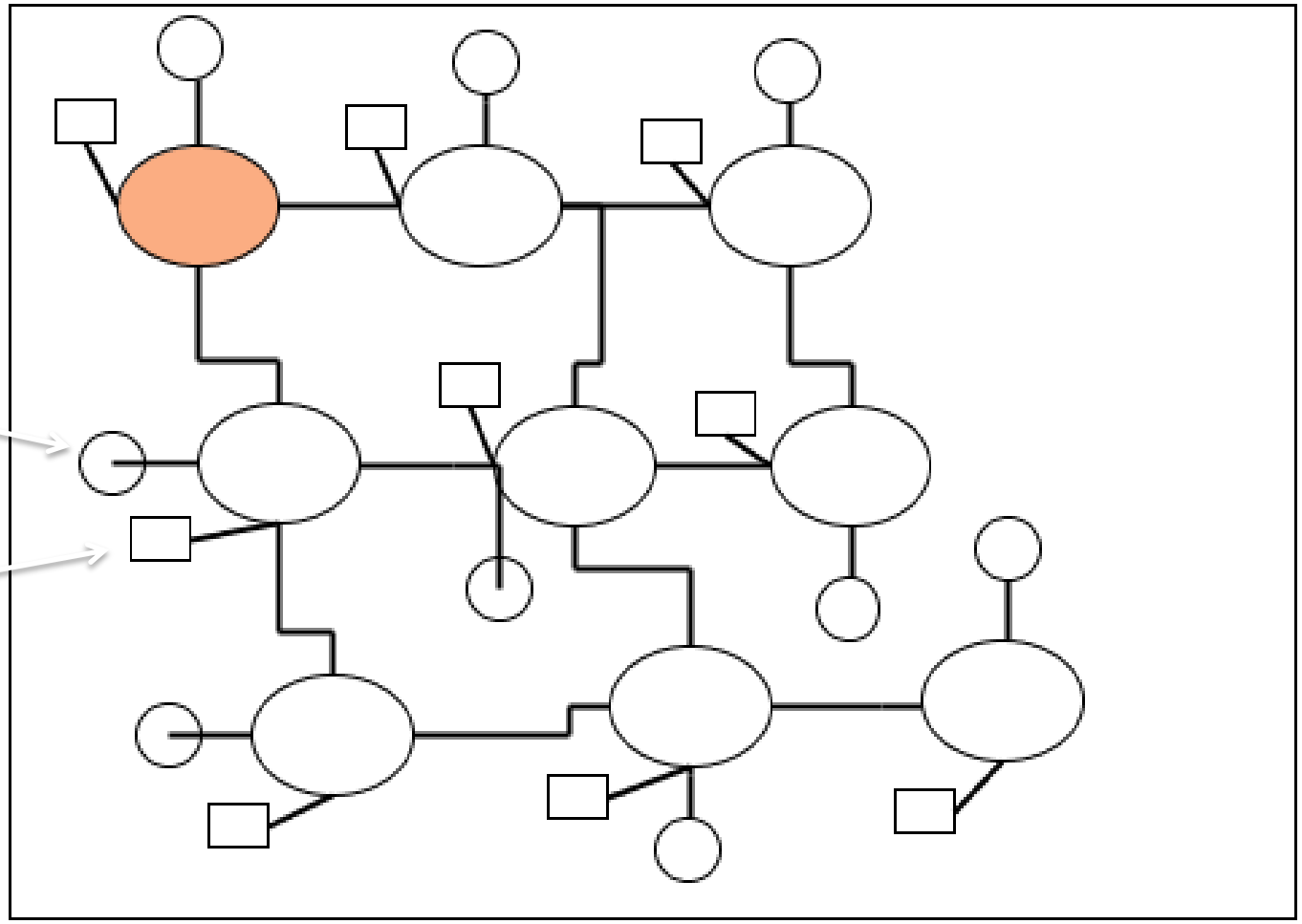


Flow mapping
An agent-based approach

- All flow districts start in an empty state
- Edges represent transition probabilities
- Each location contains:
  - Source value
  - Sink and use rates & capacities
  - Sink cache
  - Use cache
  - Carrier cache



4. ES flow propagation



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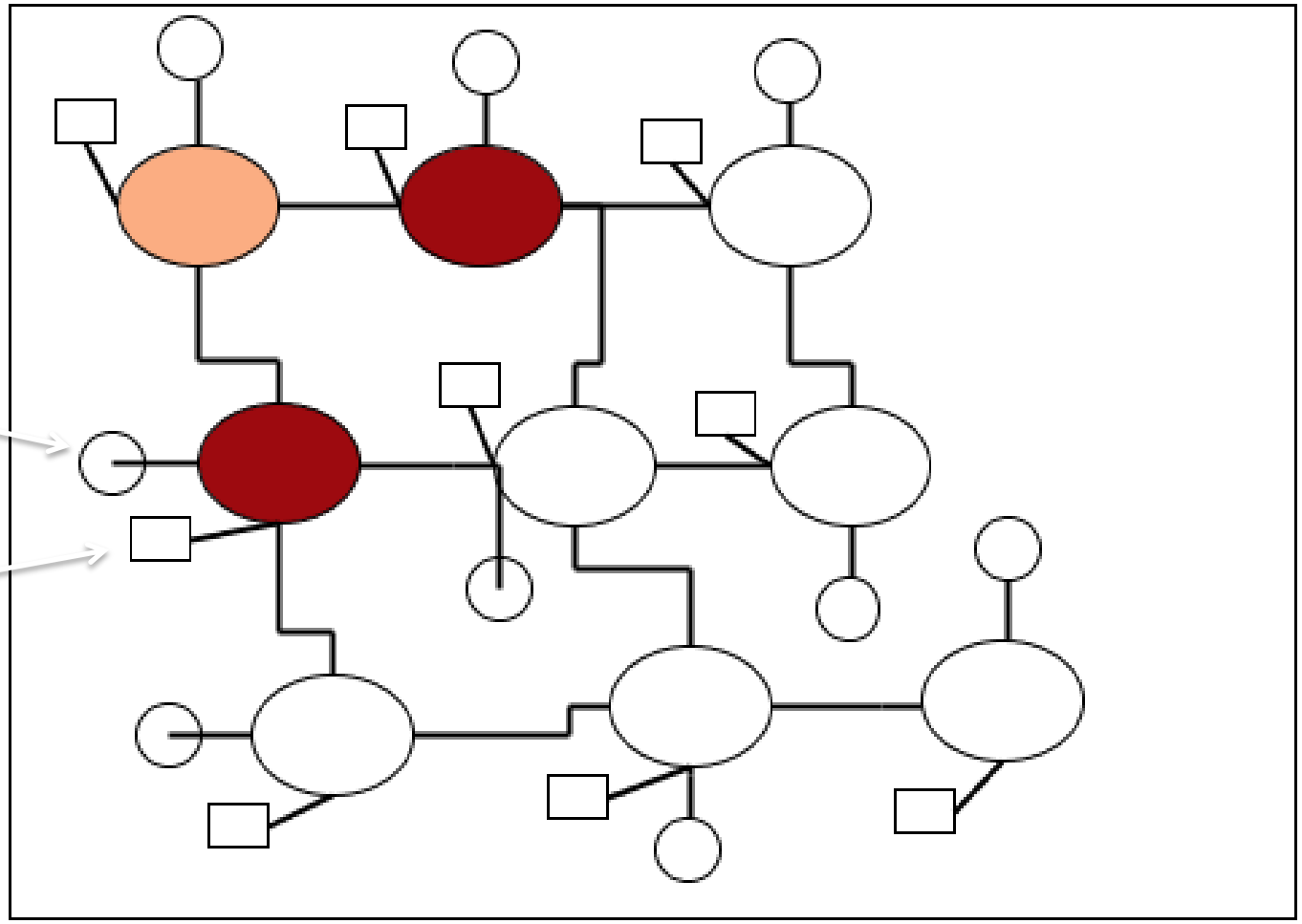

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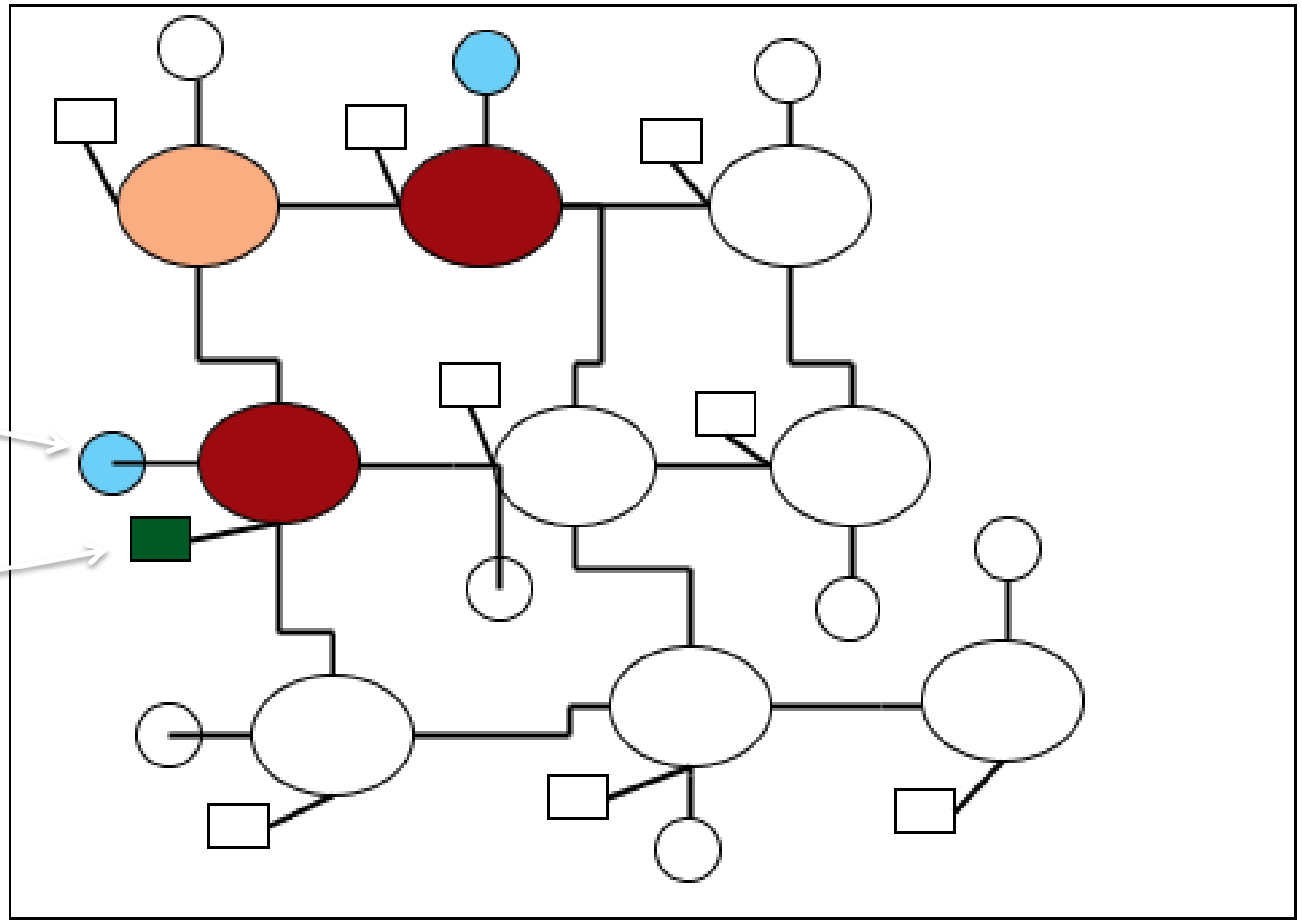

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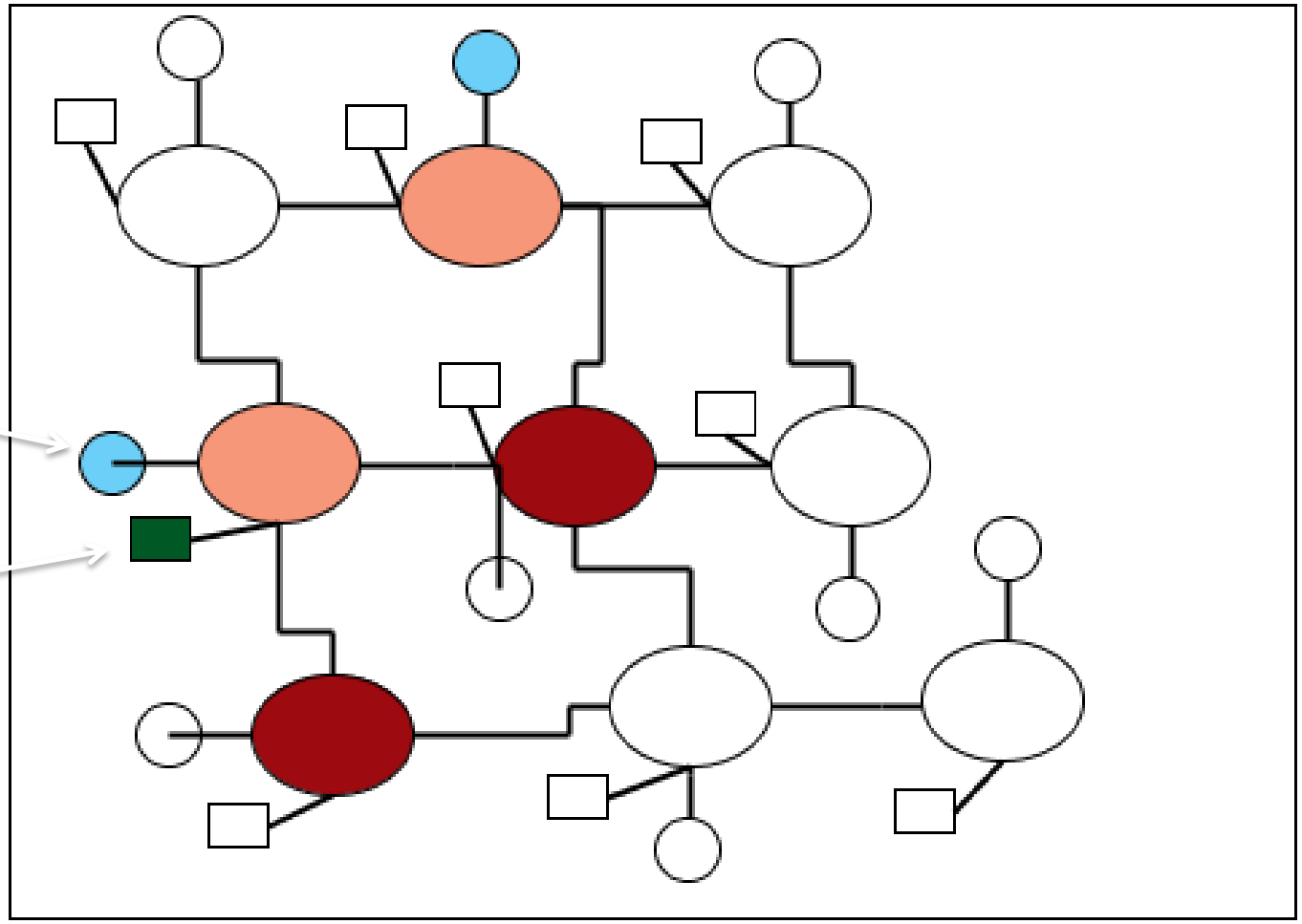

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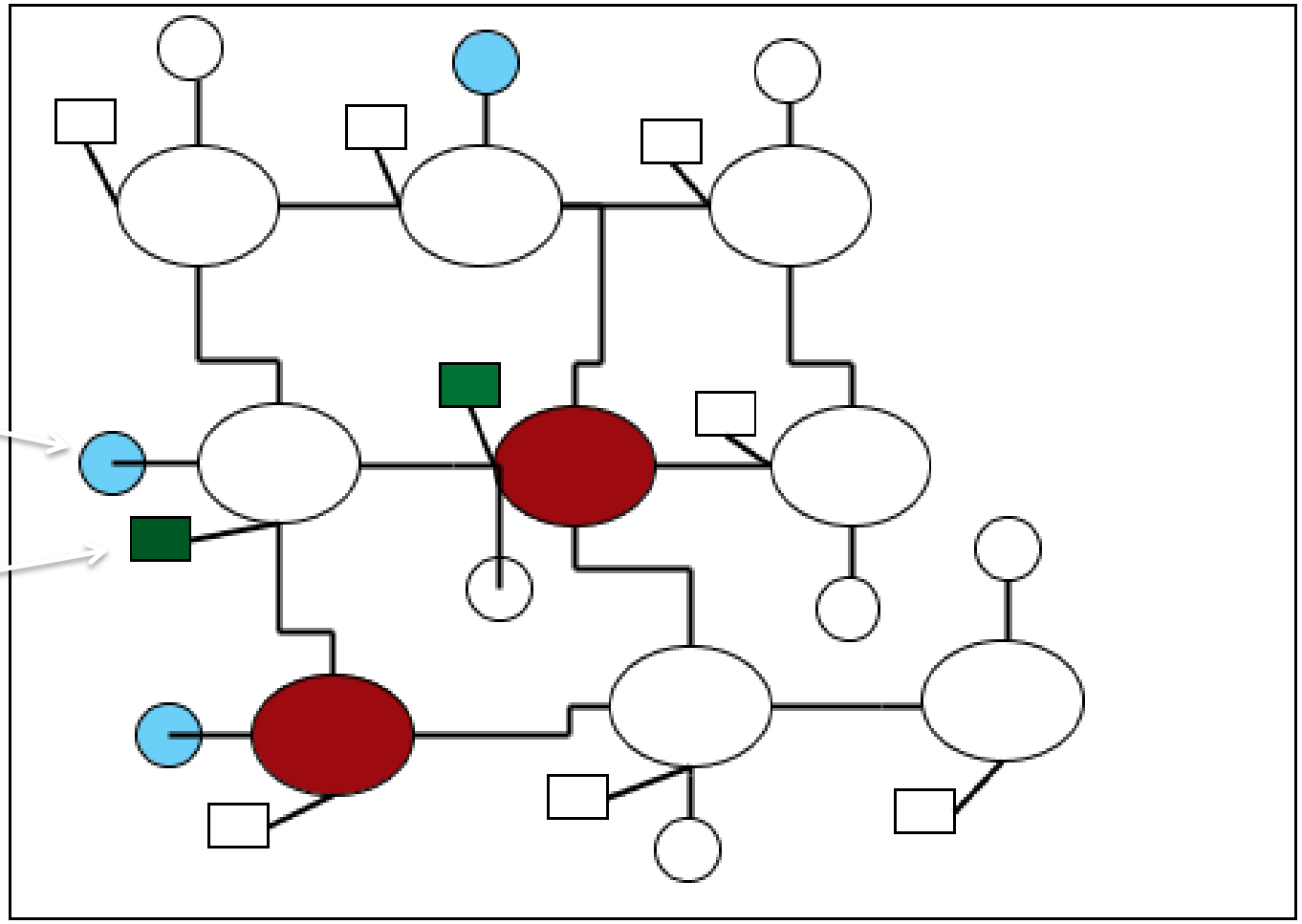

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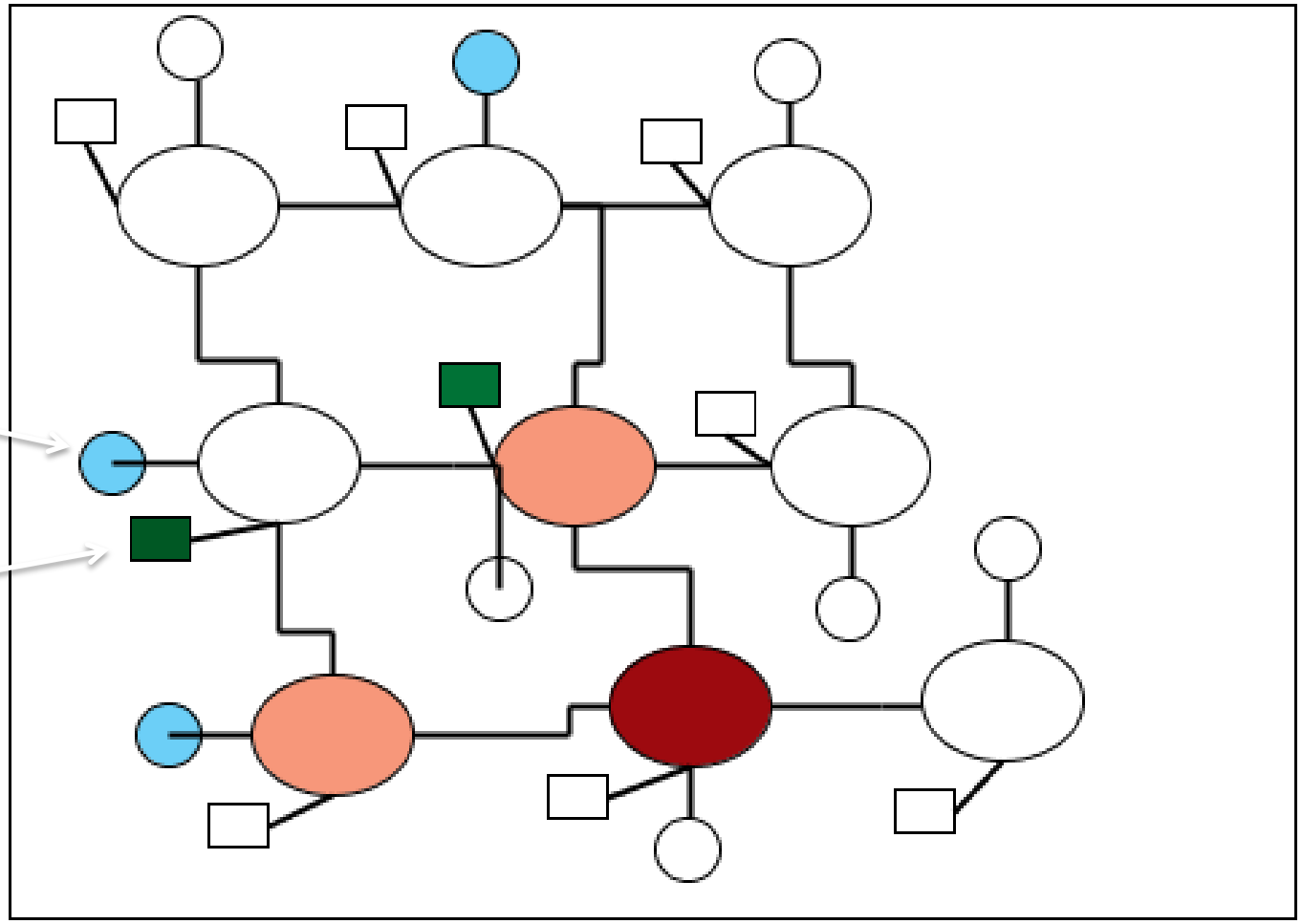

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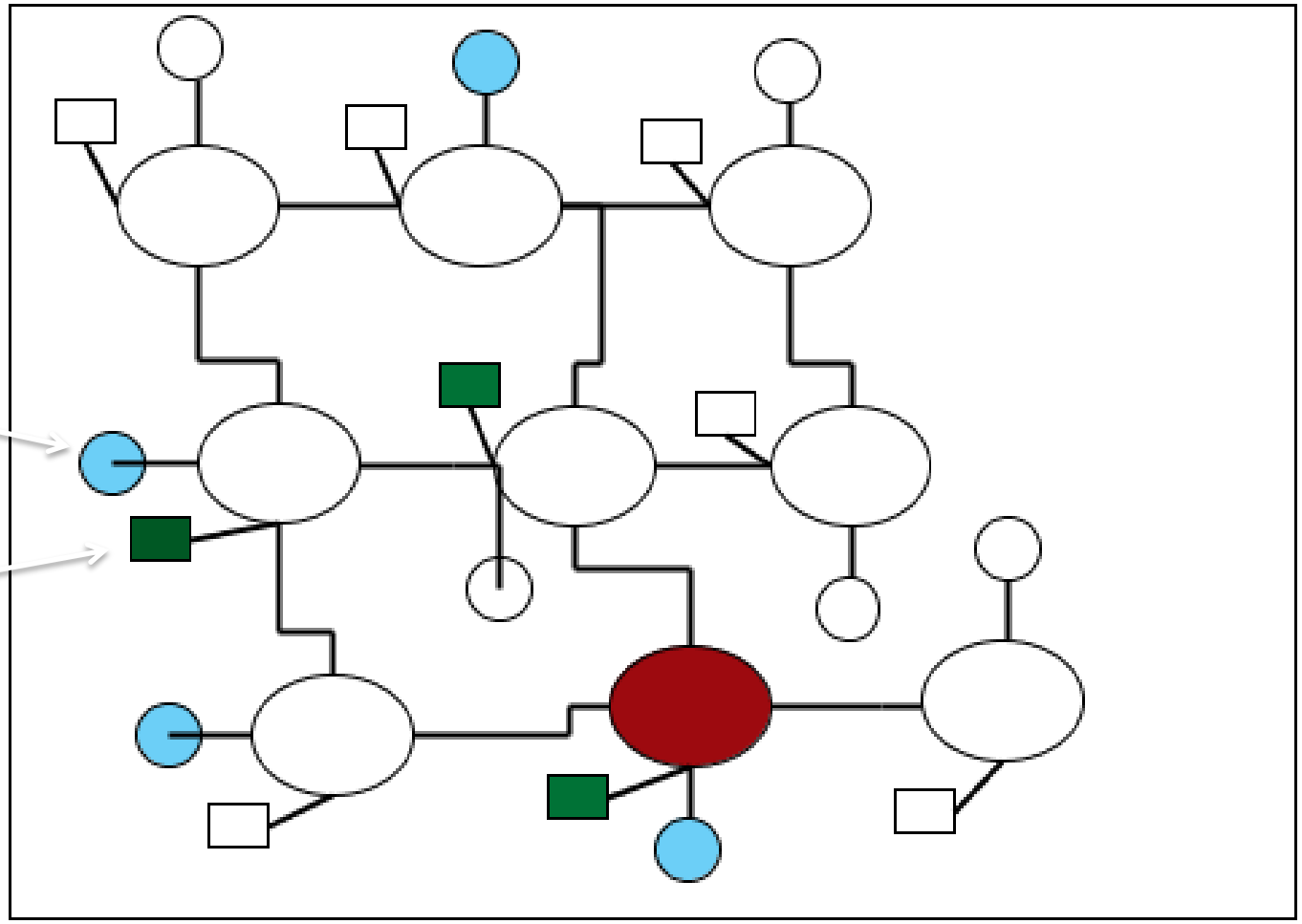

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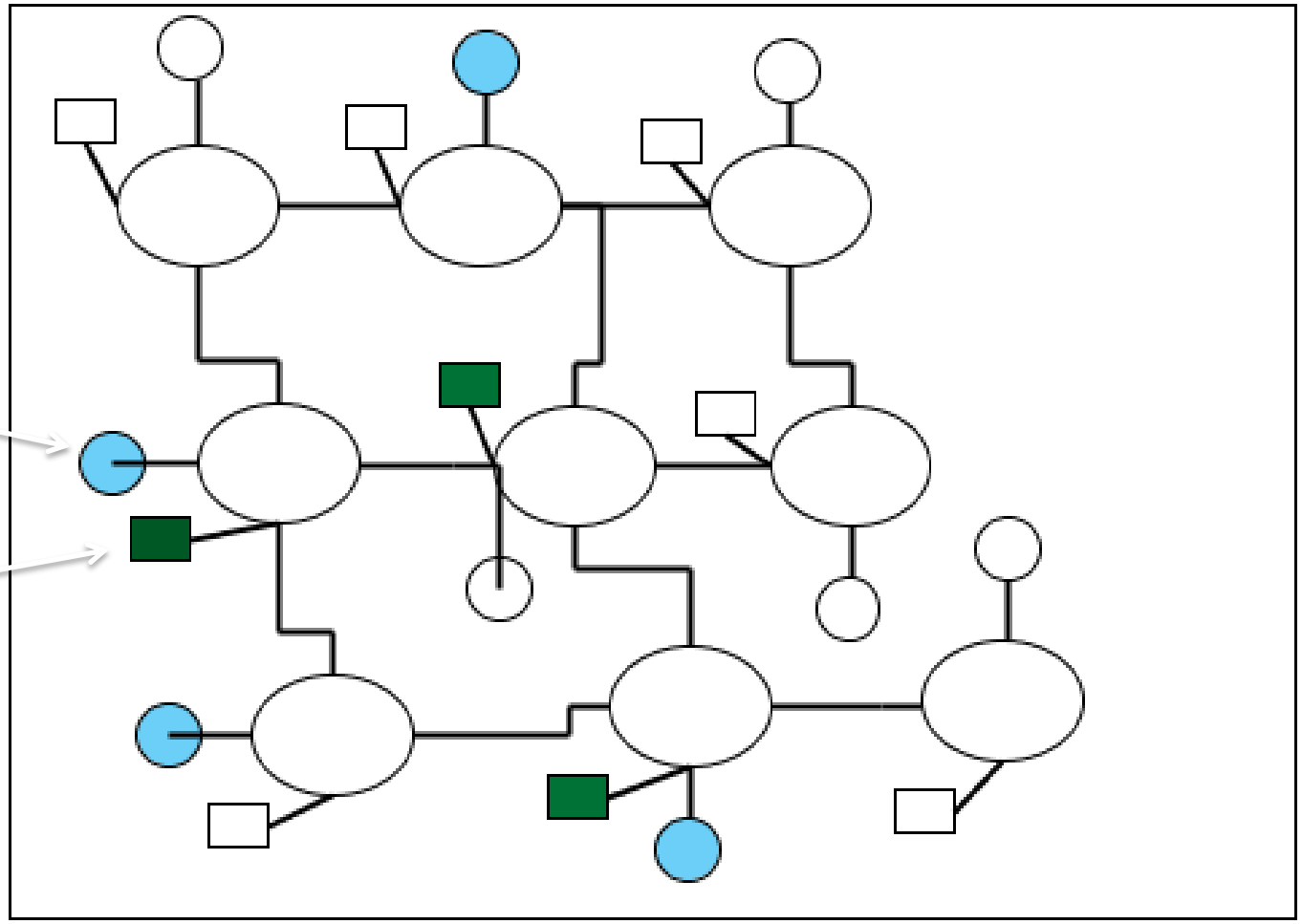
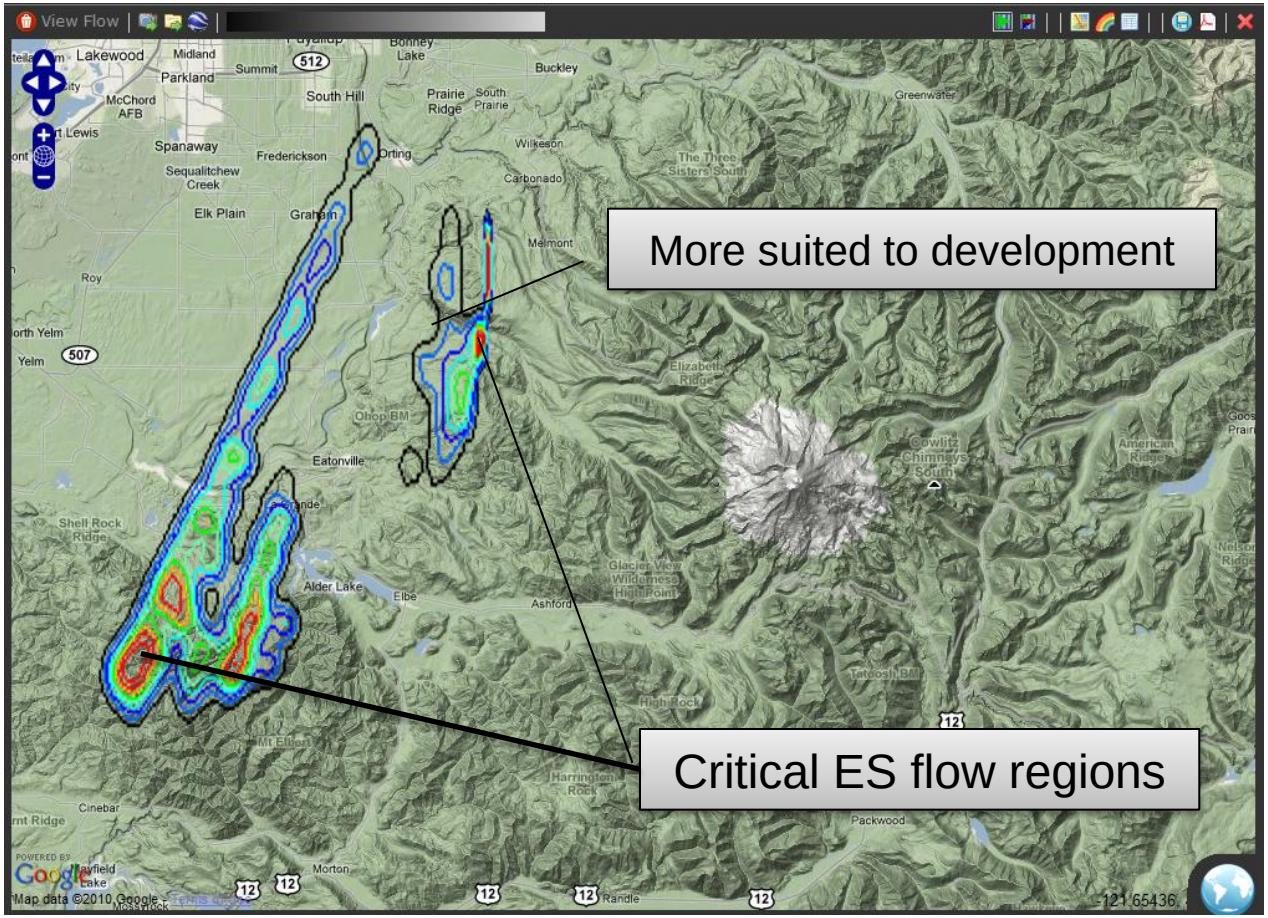


ES FLOW MAPPING

Flows connect sources and beneficiaries

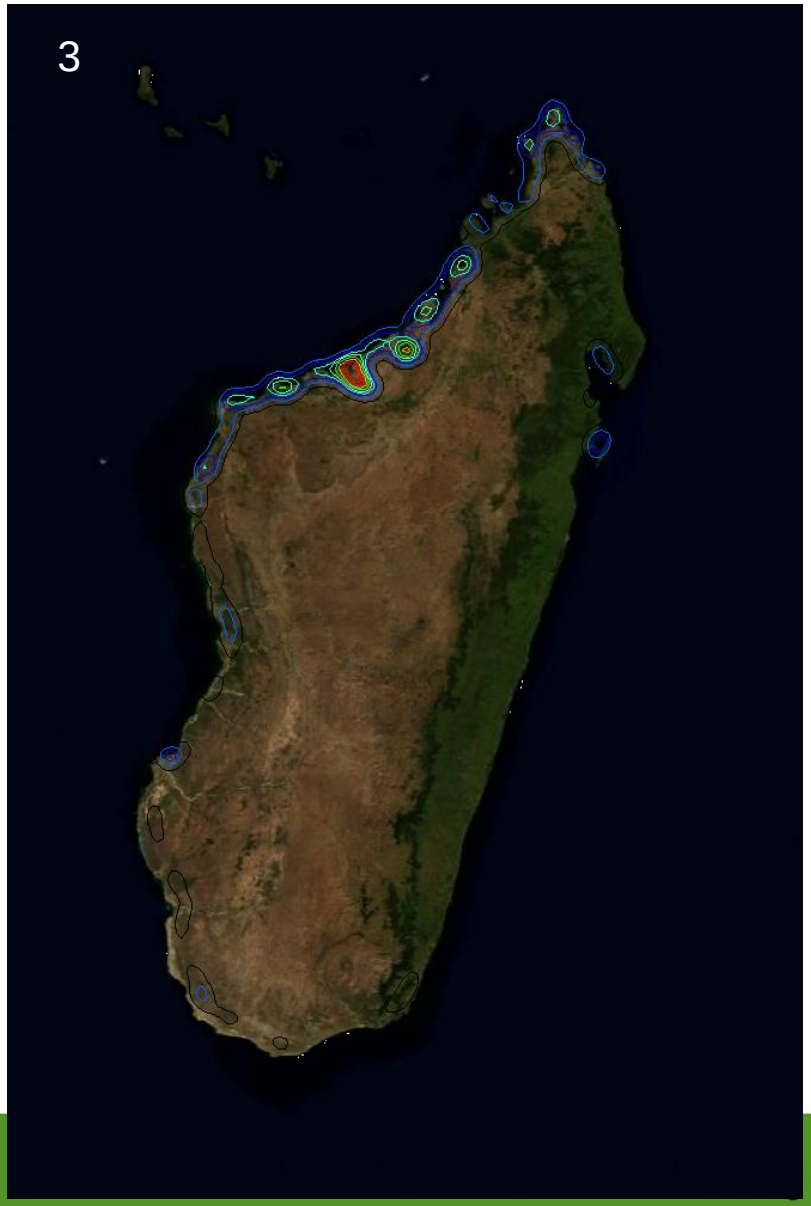


Critical flow paths show areas most critical to ensure ES flow to the intended beneficiaries.

Regions of high flow density should be protected or <u>enhanced for positive impact</u>

Regions of lower flow density can be developed without impacting ES provision.

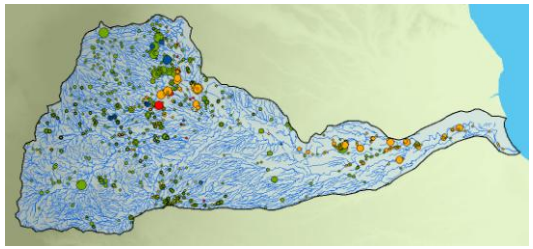
HIGHLIGHTING the SOCIAL DISTRIBUTION of ECOSYSTEM SERVICES



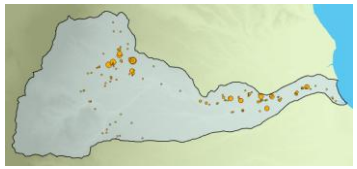
1. total demand for subsistence fisheries
2. met demand fraction
3. unmet demand fraction.

The model uses poverty, population density, pollution, habitat suitability and harvest data. Problem areas are immediately visible.

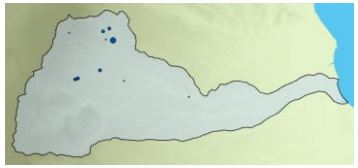
VERACRUZ water services: some results



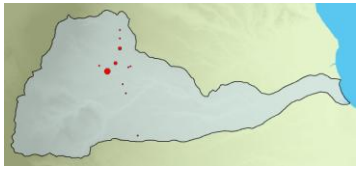
total demand from:



Agriculture

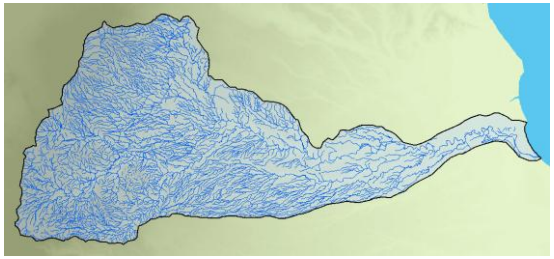


Aquaculture

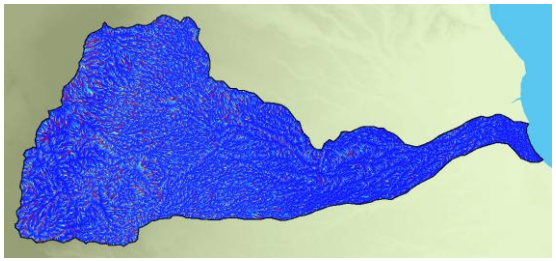


Industrial

Residential



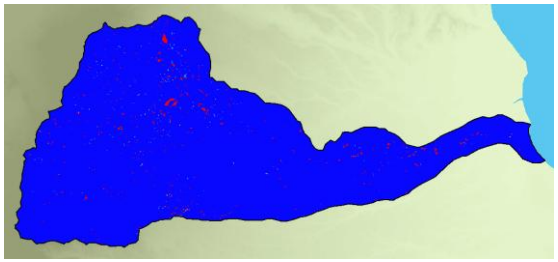
Stream network, elevation, porosity…



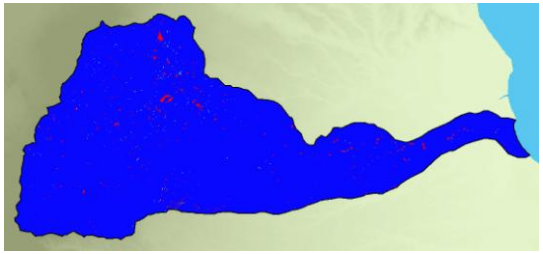
Actual flow to beneficiaries

used to compute….

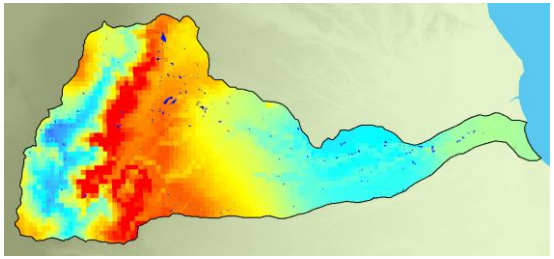
Selected results of flow modeling



Possible (usable) source



Actual surface water use



Inaccessible water source

Novel results from flow analysis

- Analysis of flows wasn't available before ARIES and computes source, sink, use and flow profiles.
- Flow analysis yields crucial maps to assist decision, such as critical flow contours, **unmet service demand** or **unused service production**.
- Quantification is based on *flow strength*, *actual use and provision*. **Policy scenarios** can be analyzed by comparing such contextual information, resulting in more accurate, beneficiary-dependent, science-based estimates of values. **Uncertainty** is preserved in flow computation and can be visualized.

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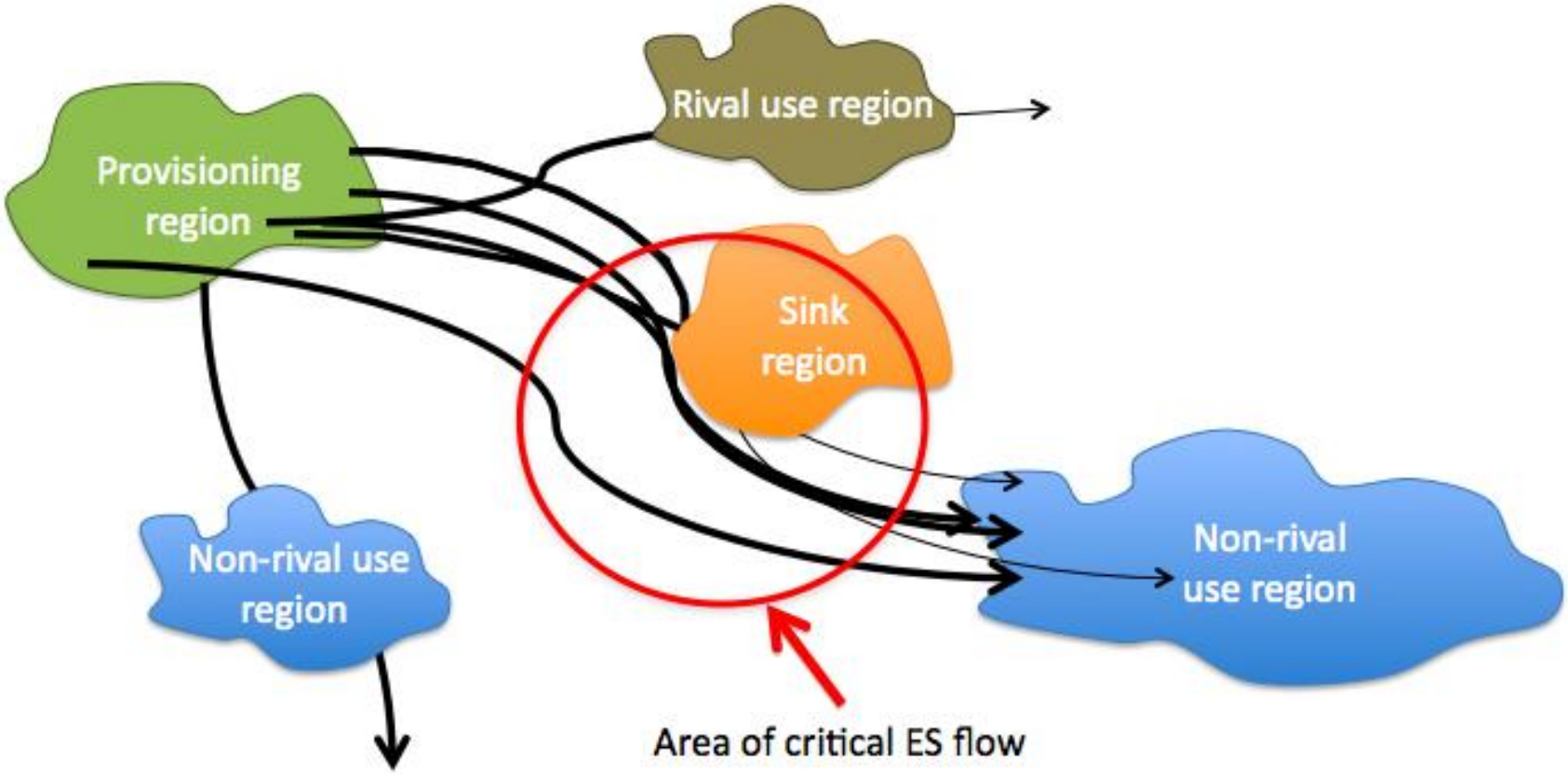
NEW AGGREGATED INDICATORS

Using information about actual flows, new overall indicators can be computed (with associated uncertainties) for:

- EFFICIENCY of provision (actual vs. potential) 0 -1
- EFFICIENCY of use (need met or unmet vs. total) 0 -1
- EQUITY of distribution (winners and losers) 0 -1
- TOTALS: actual use, actual production, unused potential, unmet need

Such indicators can be used as good objective functions in scenario analysis.

TARGETING PRECISE AREAS THROUGH FLOW ANALYSIS
applicable to source, use and sink



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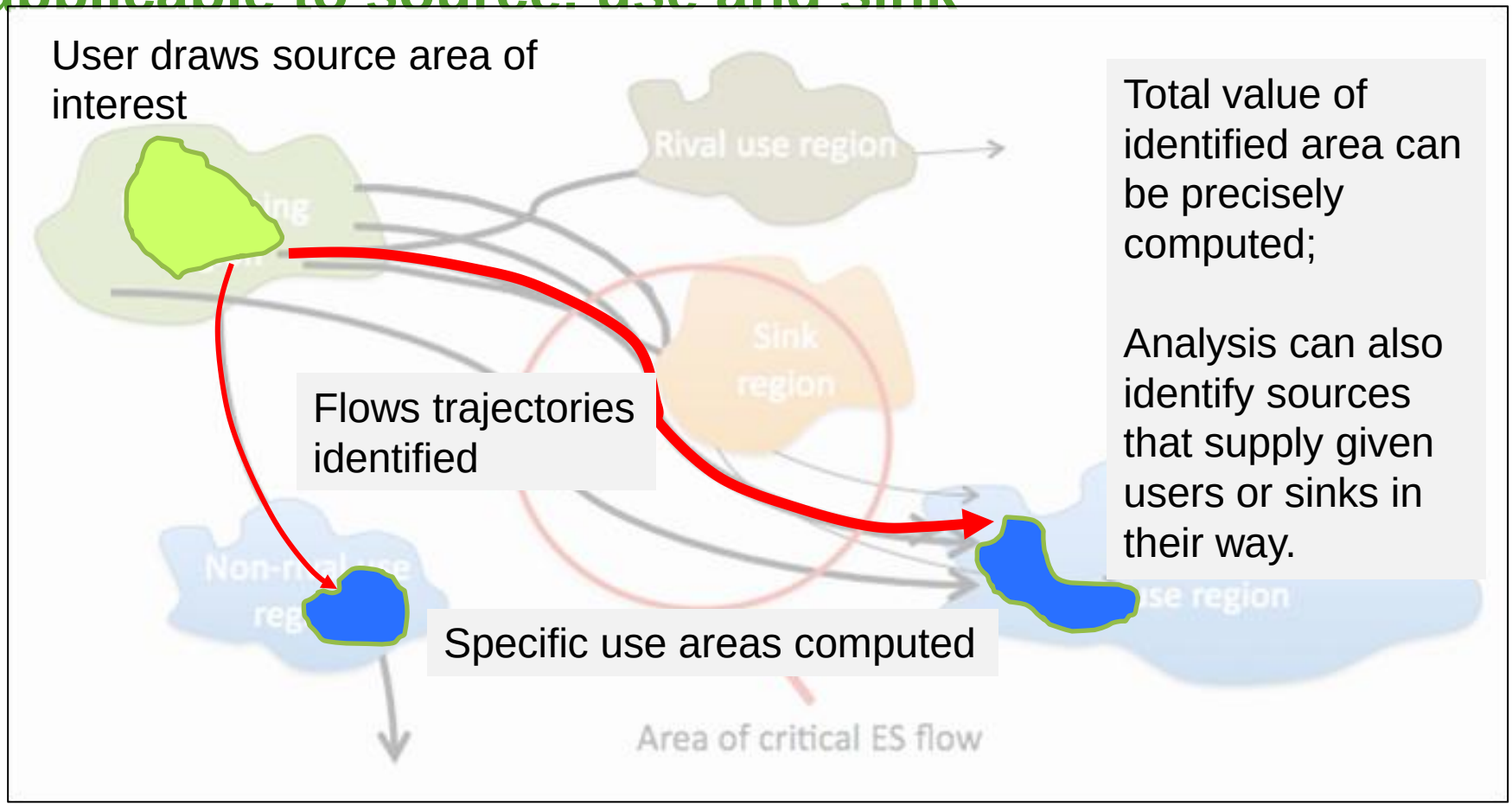


VALUATION and ARIES: getting real?

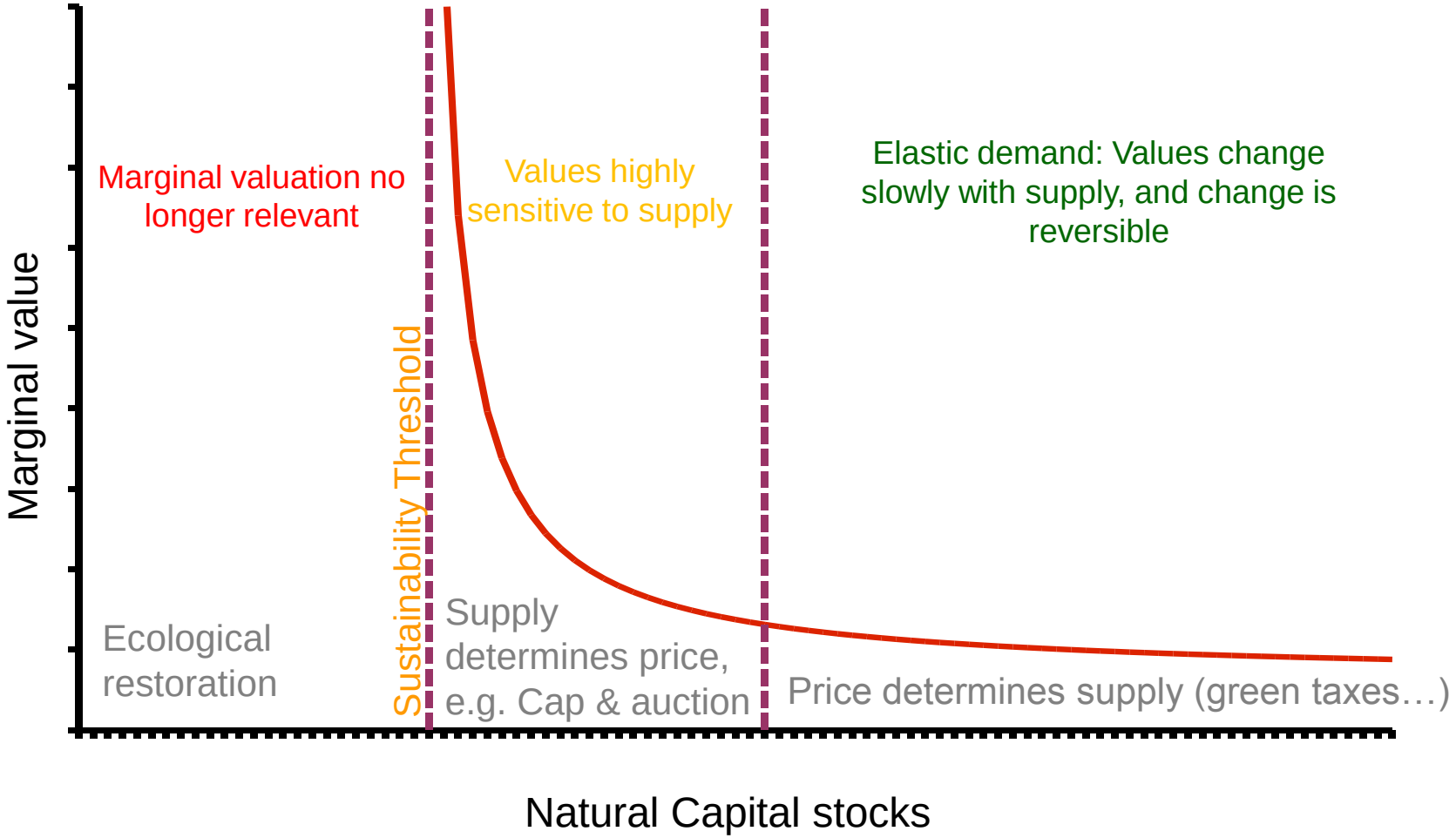
ARIES is agnostic about valuation and tries to counteract inaccuracy in the “state of the art” by incorporating:

- explicit uncertainty
- flexible definition of *value*
- flexibility and innovation in methods
- validation opportunities.

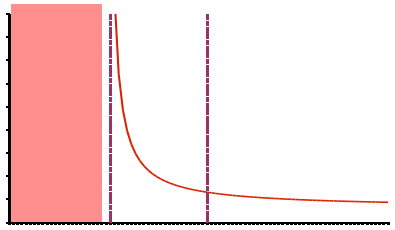
VALUE can be BASED ON:

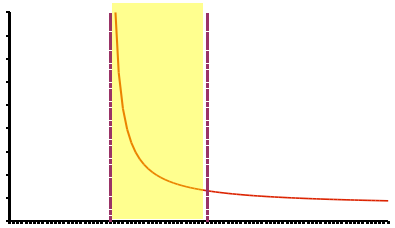
- ACTUAL or POTENTIAL physical flows or source values
- Concordance value with stakeholder priorities
  - MCA (Electre3, Prometheus, Evamix)
  - AHP
- Economic valuation
  - Bayesian and Econometric modeling can be easily integrated
  - Intelligent benefit transfer methods are in development

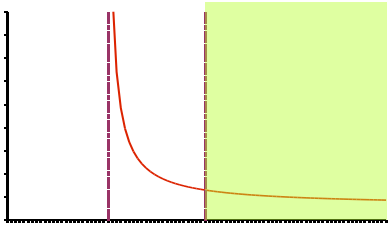
Criticality thresholds and valuation

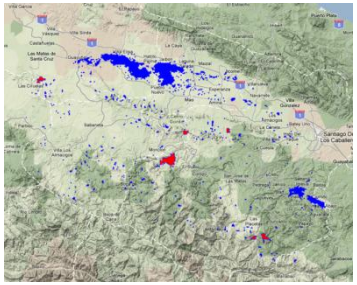


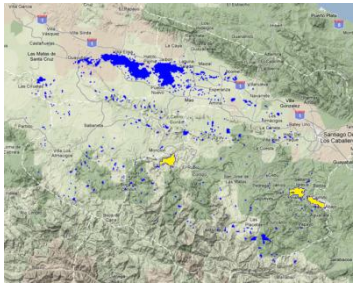
VALUATION in ARIES can be INFORMED BY CRITICALITY

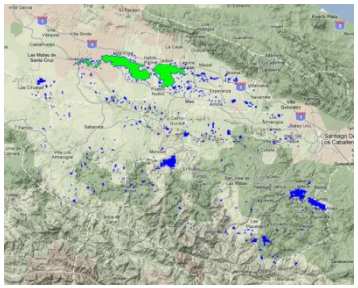












Users can set thresholds based on scenarios

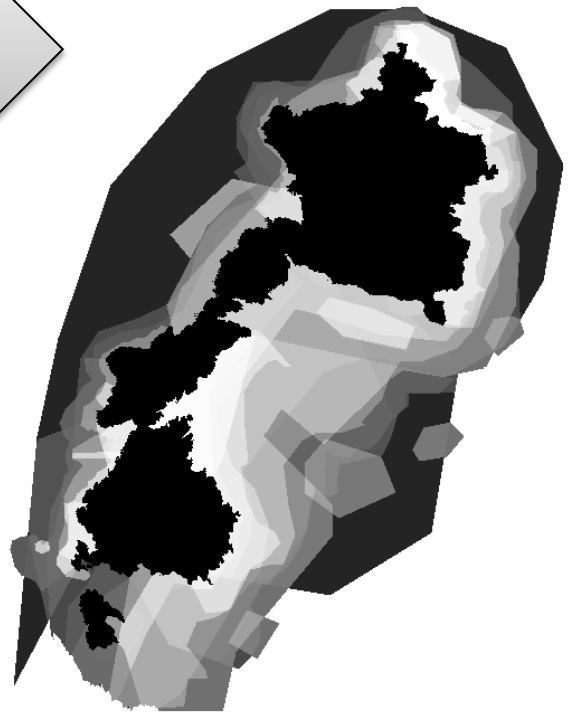
Beneficiaries are classified based on criticality of actual provision

Provision areas contributing to different beneficiary classes can be computed and valued independently

CONCORDANCE VALUE vs. MONETARY

abstract valuation = concordance between benefit flows and stakeholder priorities

	C	F	W	R	Value
Climate	1	9	9	9	**377**
Flood		1	9	3	**455**
Water			1	2	**51**
Raw mat				1	**51**



Relative importance values for benefits are input by users

Overall value map is recalculated to reflect stated priorities in each scenario of management

Concordance values are the equivalent of value to stakeholders, and vary between 0 (no value) to 1 (complete concordance)

ARIES and economic valuation

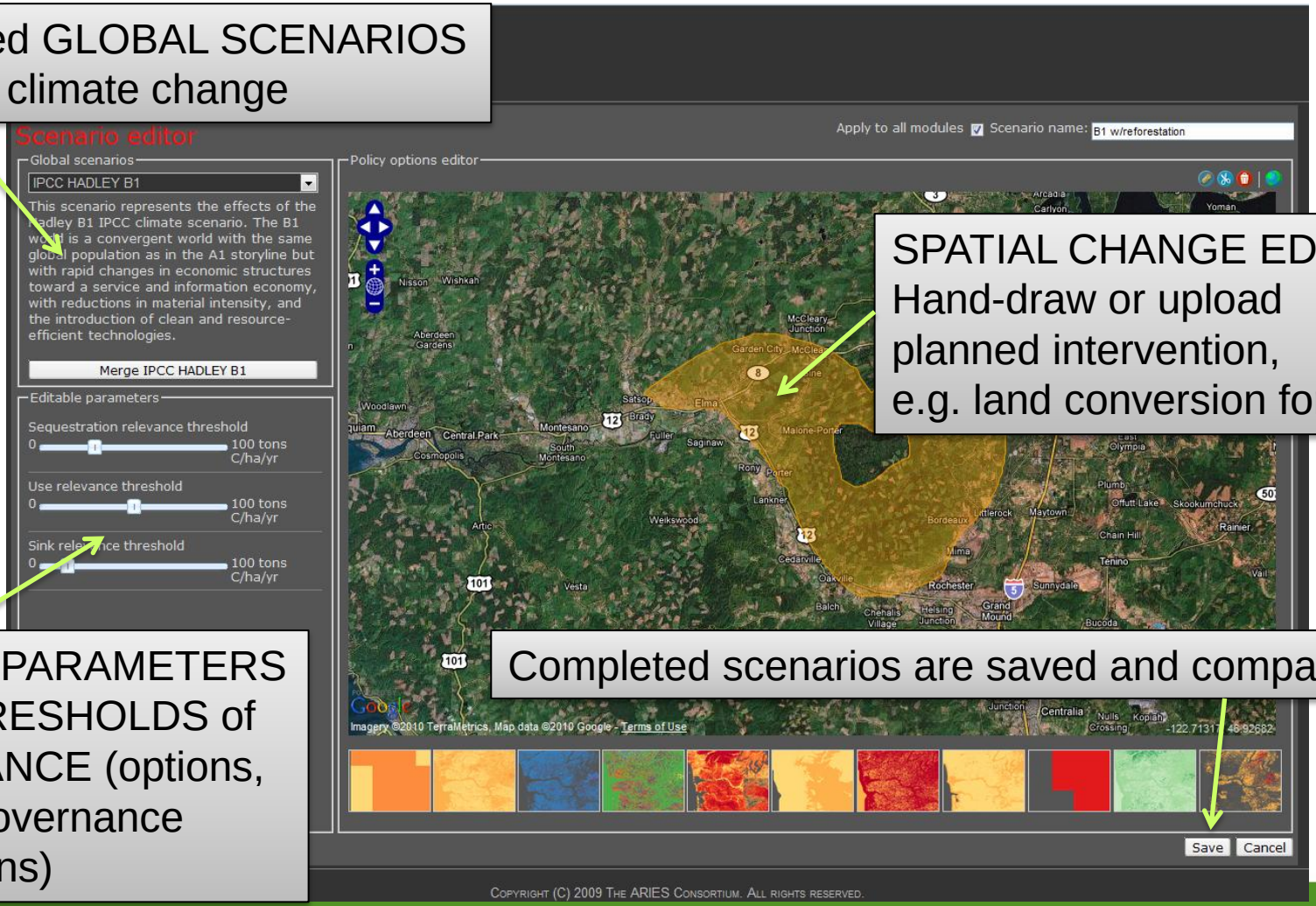
- Primary valuation:
  - WTP surveys, hedonics, travel cost, consumer expenditures, avoided/replacement cost

- Secondary valuation:
  - *Value transfer:* apply primary values from elsewhere to site of interest
  - Function transfer
    - Land use driven
    - Traditional multiple regression
    - Bayesian multiple regression
    - **Artificial Intelligence mediated (choice of source studies and transfer function learning)**
    - **Flow-based**
- Ecological-economic modeling

Ex-ante scenario definition

Global change scenarios can be merged with local land use changes

Pre-defined GLOBAL SCENARIOS
e.g. IPCC climate change

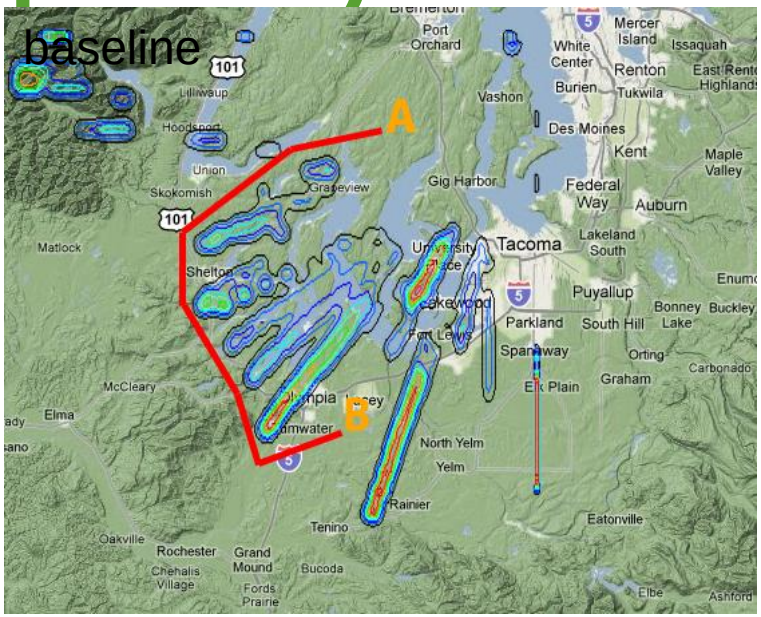


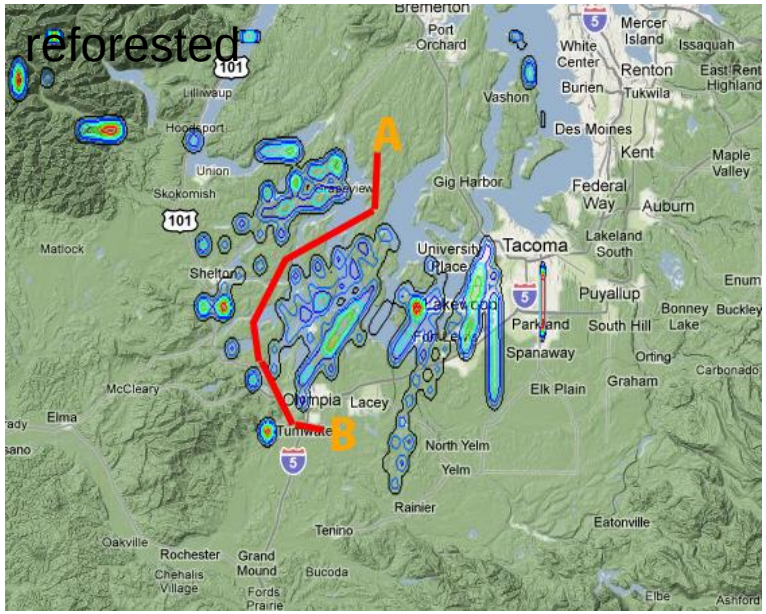
SPATIAL CHANGE EDITOR
Hand-draw or upload
planned intervention,
e.g. land conversion forest

MODEL PARAMETERS and THRESHOLDS of RELEVANCE (options, law or governance indications)

Completed scenarios are saved and compared

Routing linear features (roads, pipelines)

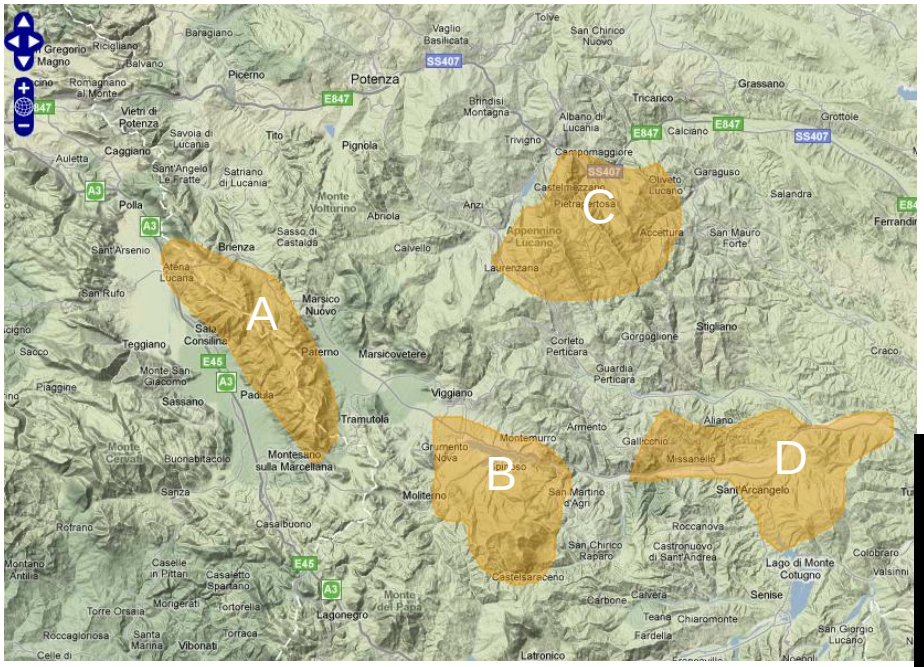




Scenario 1: routing that minimizes impact to flows of ES under *business as usual* scenario. A long feature is required to avoid impacting water provision.

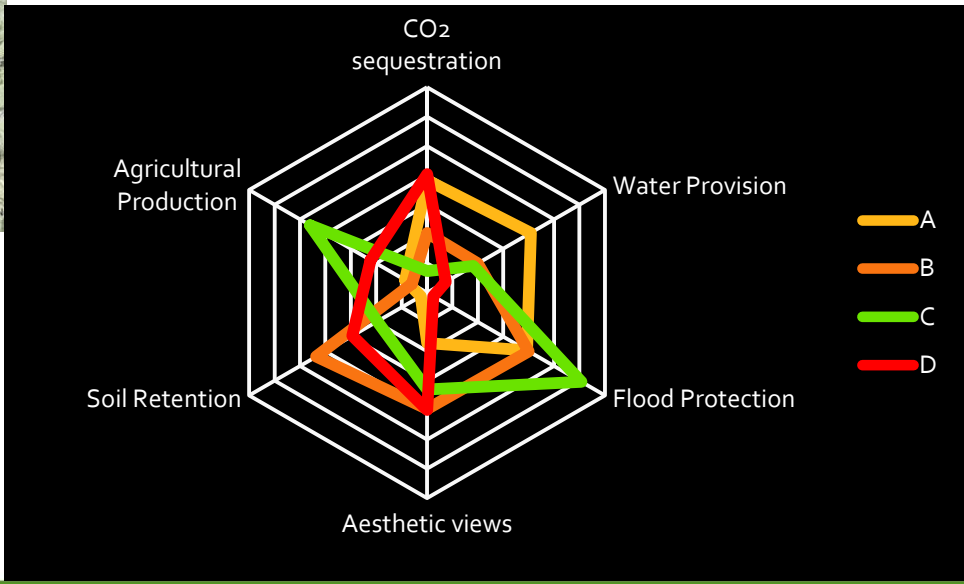
Scenario 2: routing that minimizes impact on flows of ES with reforested corridors. Shorter feature offsets reforestation costs.

Identification and ranking of areas for offsetting



ARIES can produce a full ES profile for a set of areas under consideration for offsetting, under baseline or ex-ante intervention scenarios.

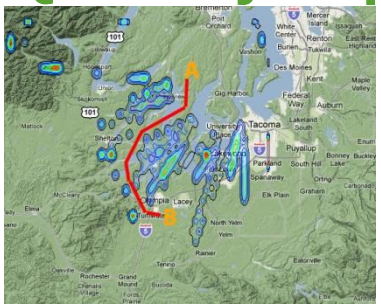
Such profiles help selection of areas and documentation of ES offsets.

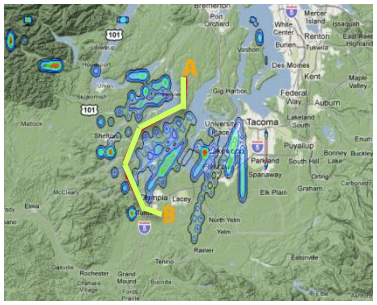


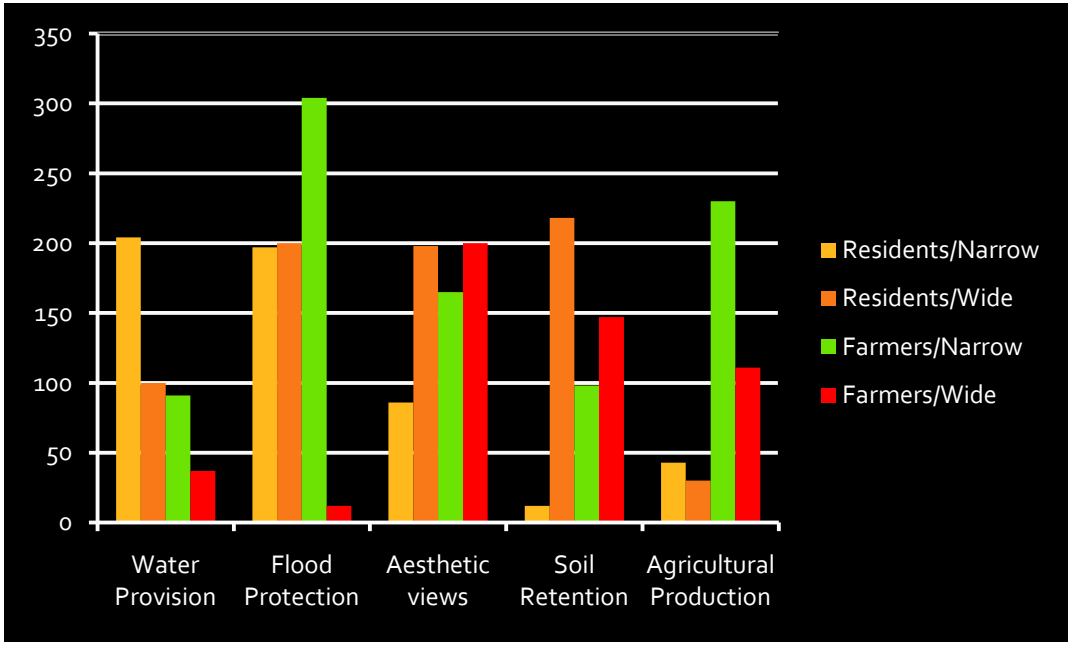
Multiple Criteria analysis allows customizing the ES profiles to pre-existing priorities or legal constraints.

Scenario based quantitative valuation

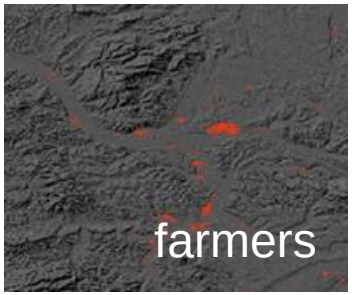
Quantify impact of choices on specific stakeholder groups

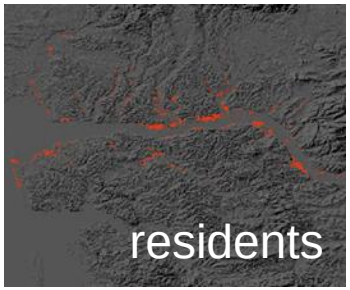






Two alternative options (different buffer zone widths) evaluated for impact on ecosystem services…





…against the different needs of two different stakeholder groups.

THANK YOU
For more information:

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