Ecosystem Services:
a complex issue

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Re-phrased as “asking 5 questions”

- How does this ecosystem contribute to human well-being?
- What are the benefits?
- To whom? (who are the beneficiaries)
- How is the service generated?
- How do benefits reach people?

The ARIES vision

Science and technology to support an improved ecosystem services scientific narrative

Quantify the potential **provision** of ecosystem services, their **actual and potential use**, and the **values generated** in **nature/society transactions,** using models in flexible, scalable and intelligent ways.

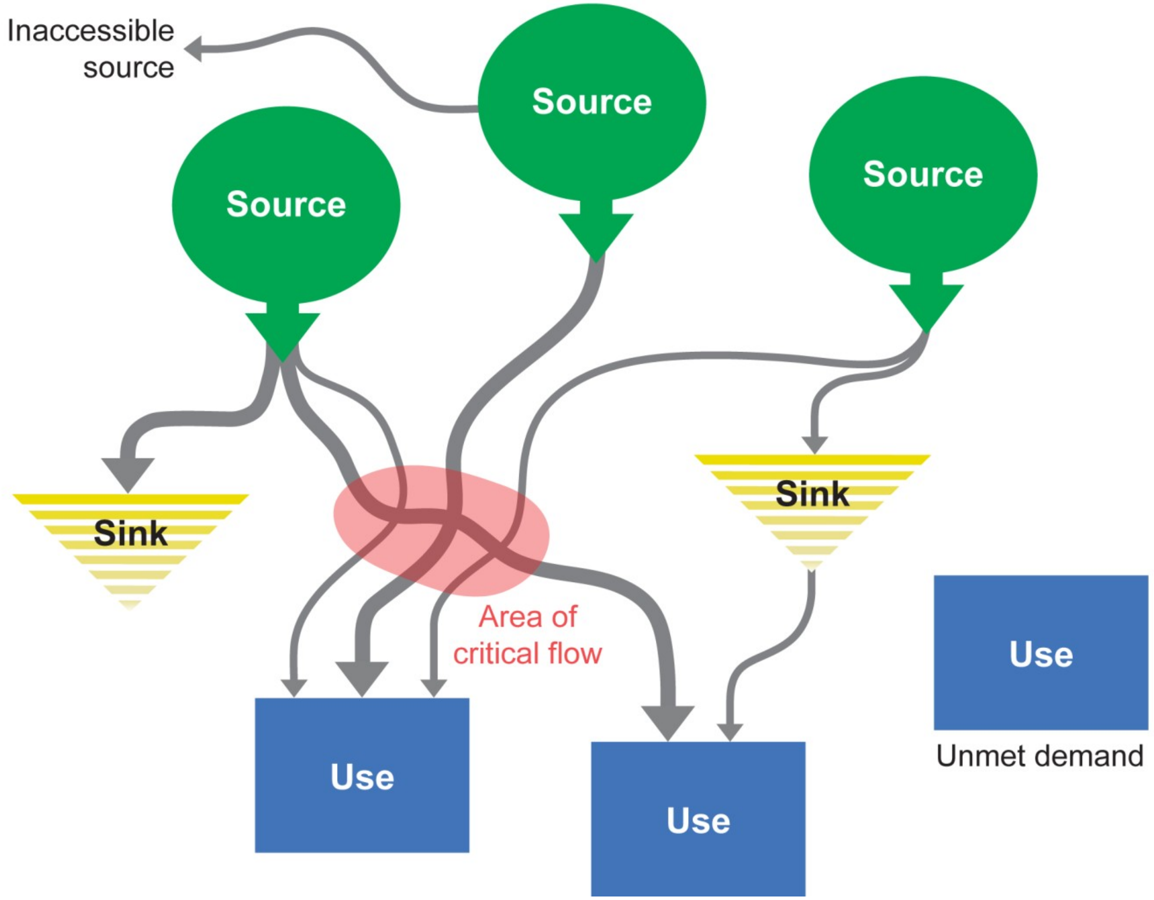
Artificial intelligence is used to:

1. find **agents** of *provision*, *transaction* and *use*
2. **assemble data and models** from the network to compute **flows** of value between them, in the best possible assessment for the context.

Overarching goal: pay due attention to

3. **Scale(s)** and **structural complexity** (agents);
4. **Temporal dynamics** and **functional complexity** (flows, feedbacks, tipping points);
5. **Uncertainty** and its role in decision

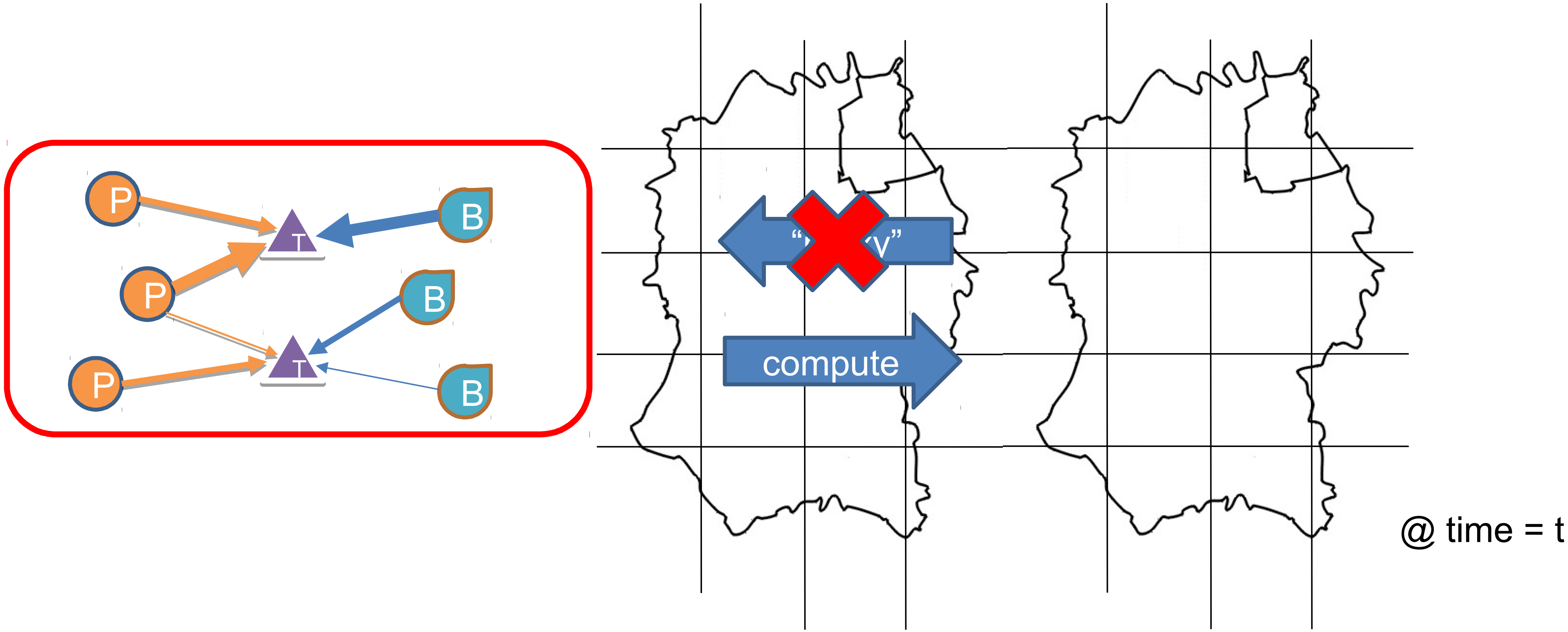
Technology allows **SIMPLE USE** of **SOPHISTICATED MODELS!**



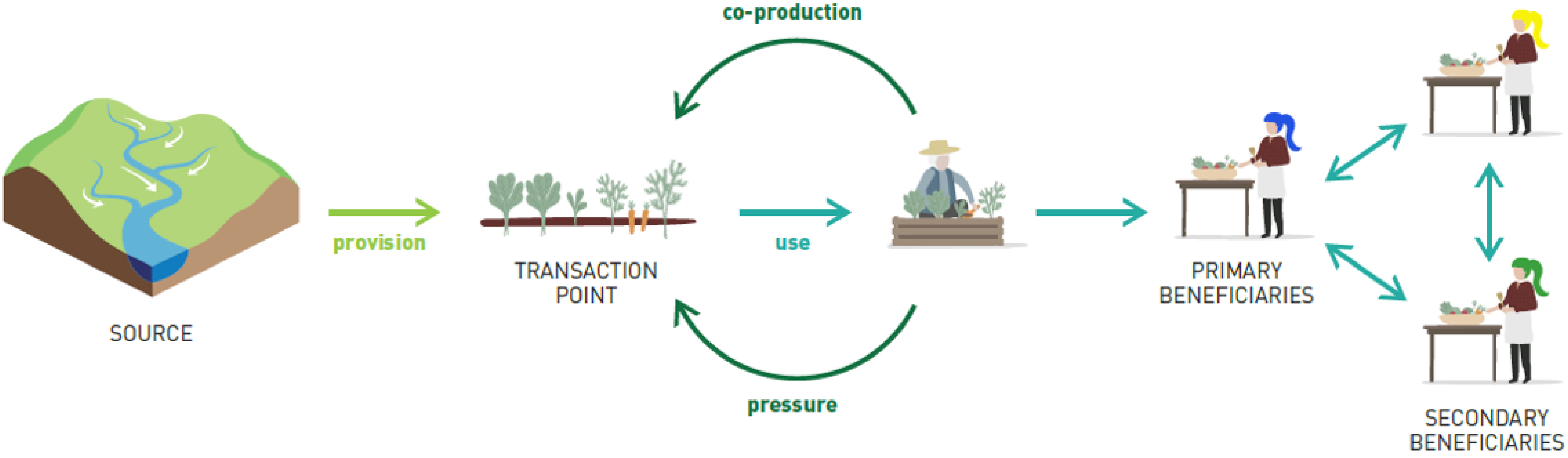
from Villa et al. 2014, PLoS One

Accounting for human-natural interactions

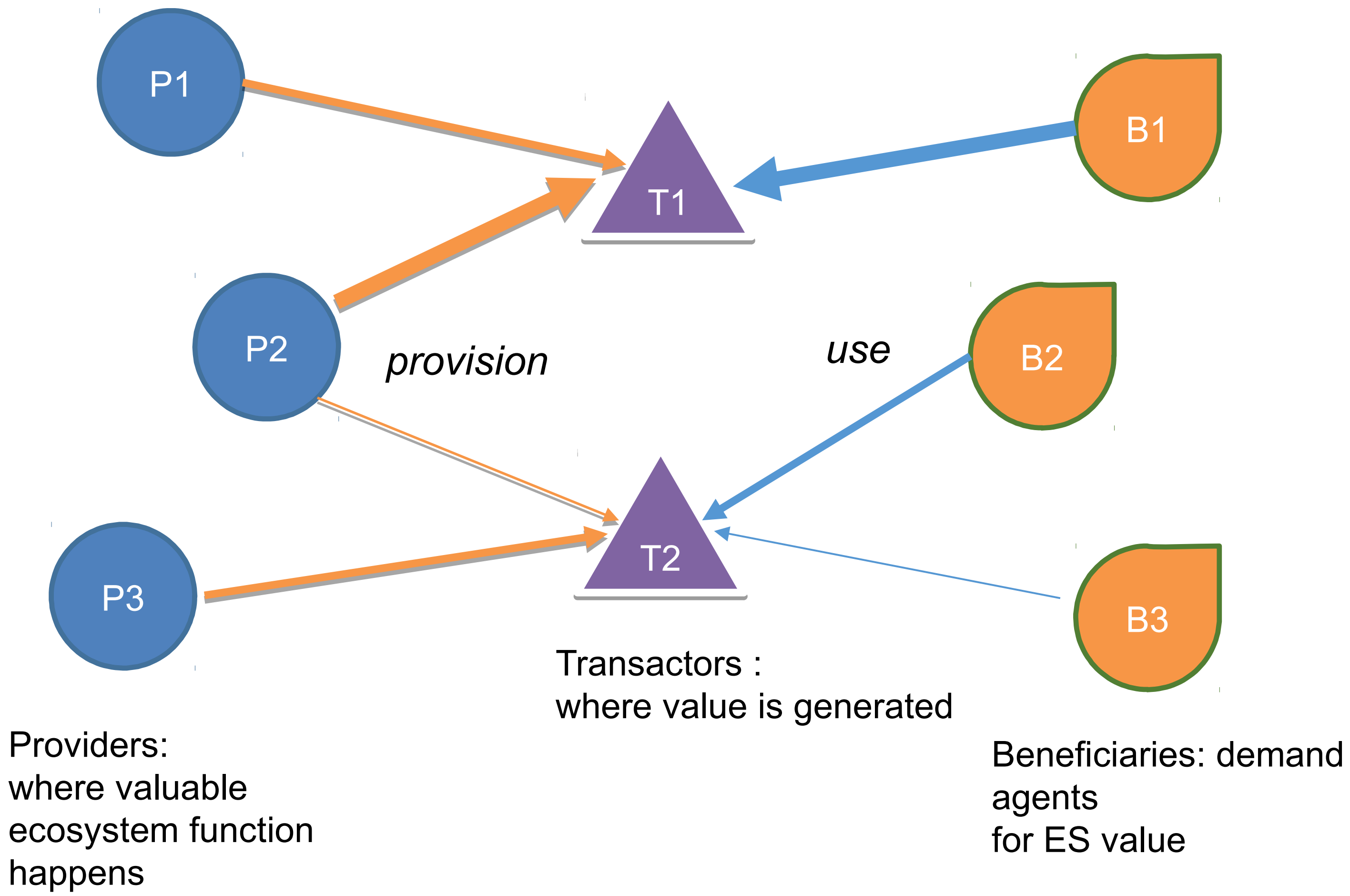
- Extend "the ES as a mapped stock" paradigm: we are better than that
- ES are the throughput of the values exchanged within a network of eco-social agents - a dynamic process



A social-ecological system approach



Semantics of an ES flow network



Provision = the process that defines the Provider -> Transactor relationship

Use = the process that defines the Beneficiary -> Transactor relationship

ES flows are the throughput of these processes.

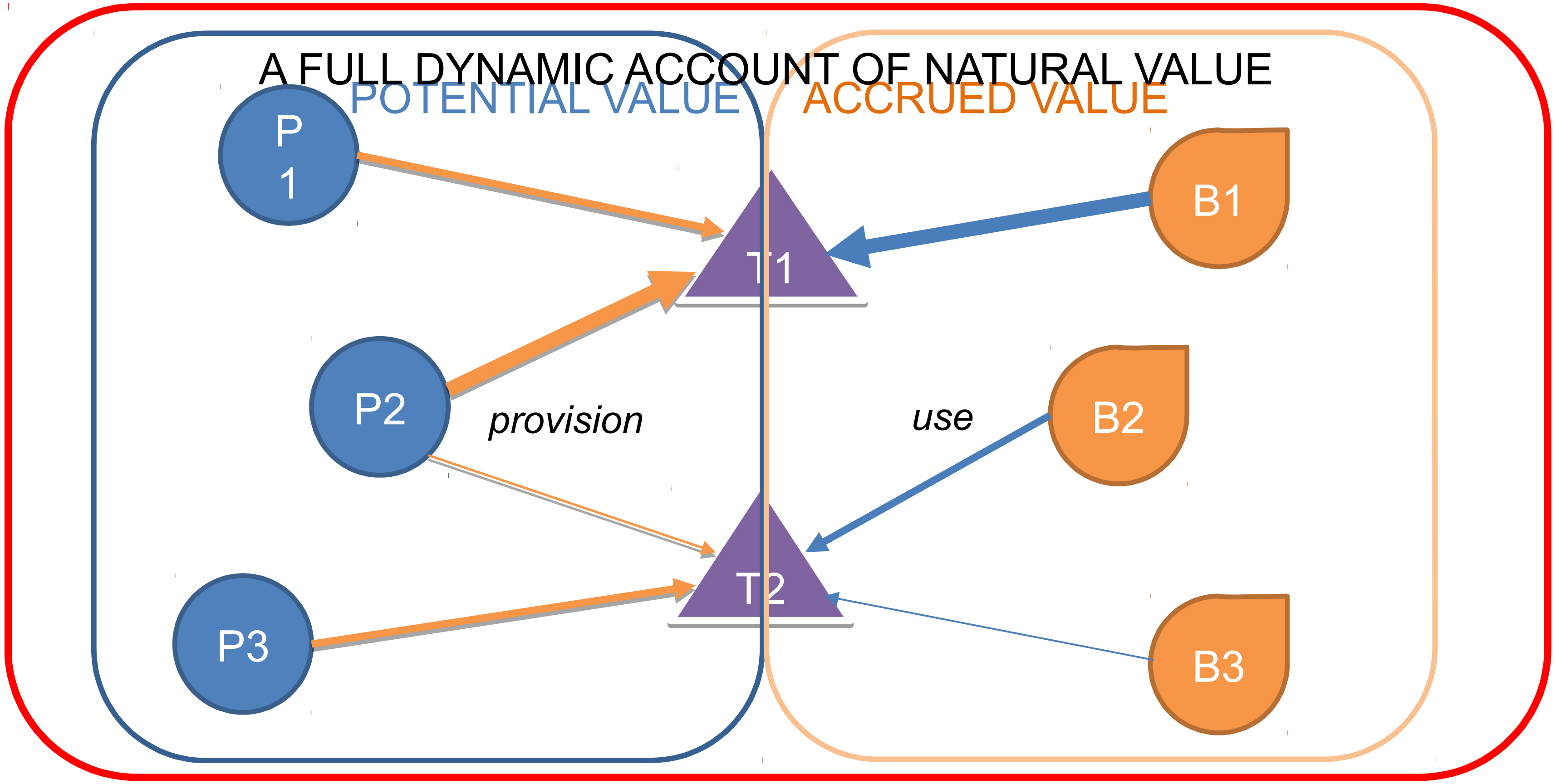
Specific benefits specialize this model to define each agent. For example, residential water ES:

Provider = Watershed
Transactor = Well, IntakePoint
Beneficiary = Household or Village

SMM establishes the identity of each based on **context** and **scale**

Socio-ecological systems as interactive networks

An agent network defines both structure and function for any system where ecosystem services are expressed



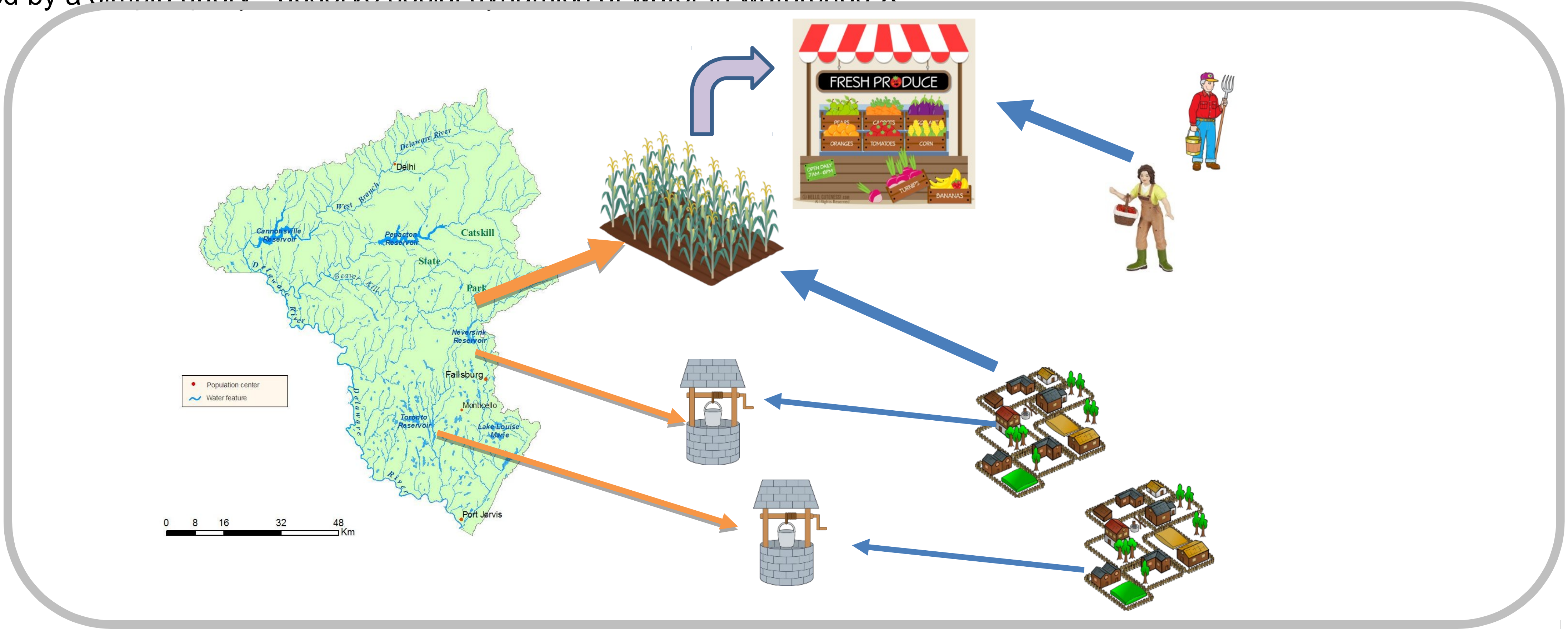
Providers (e.g. forests, watersheds): where valuable ecosystem function happens

Transactors (e.g. wells, crops, atmosphere): where natural value is generated

Beneficiaries (e.g. farmers, coastal dwellers): demand agents for natural value

Example: building an eco-social flow network

Triggered by a simple query: “observe social dynamics of water in watershed X”



The model for the *system* then creates and classifies all relationships, starting with *provision* (provider->transactor)…

…and following with use (beneficiary <- transactor), building a (potentially) differently scaled model for each flow.

Intermediate transactors (e.g. markets) are brought in according to the ontologies. They can be local or remote.

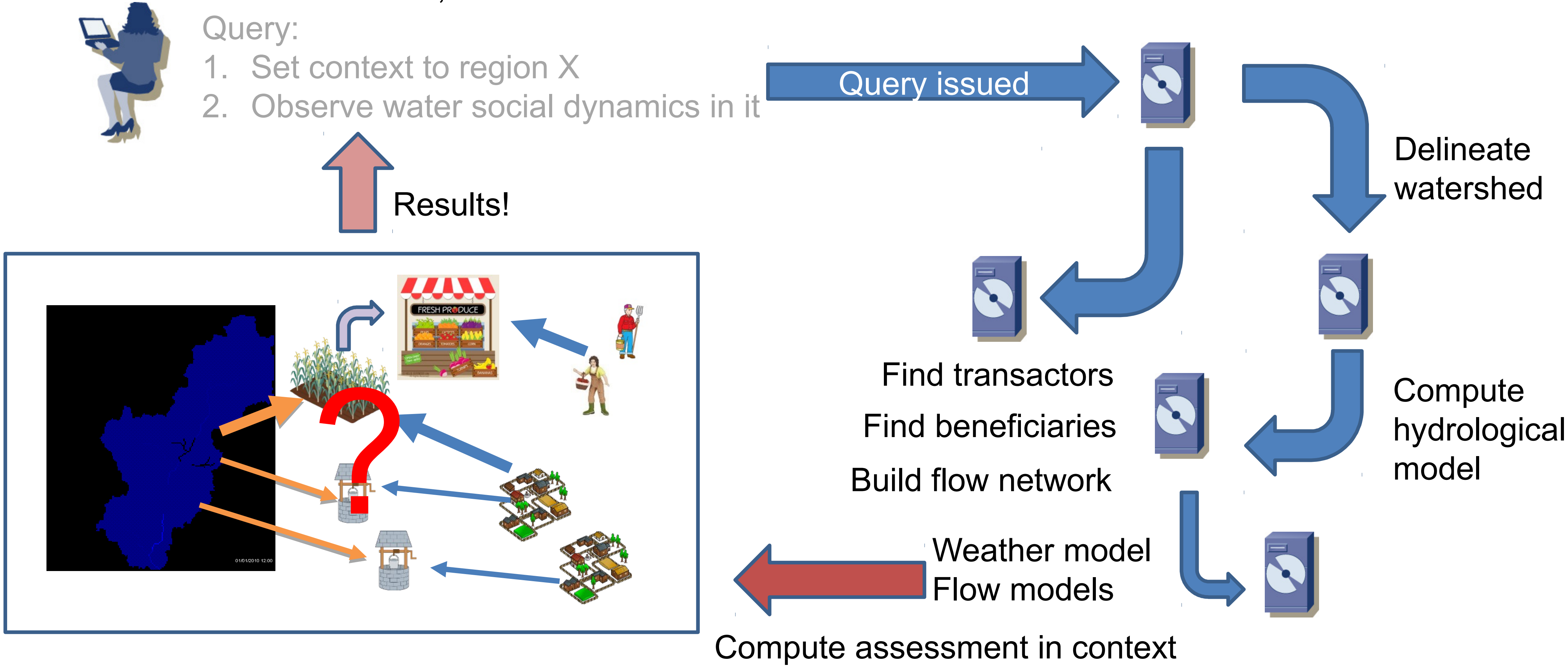
Providers (e.g. forests, watersheds) are first identified and built by the AI engine.

The ontologies define types of Transactors (e.g. wells, crops, atmosphere), identified last.

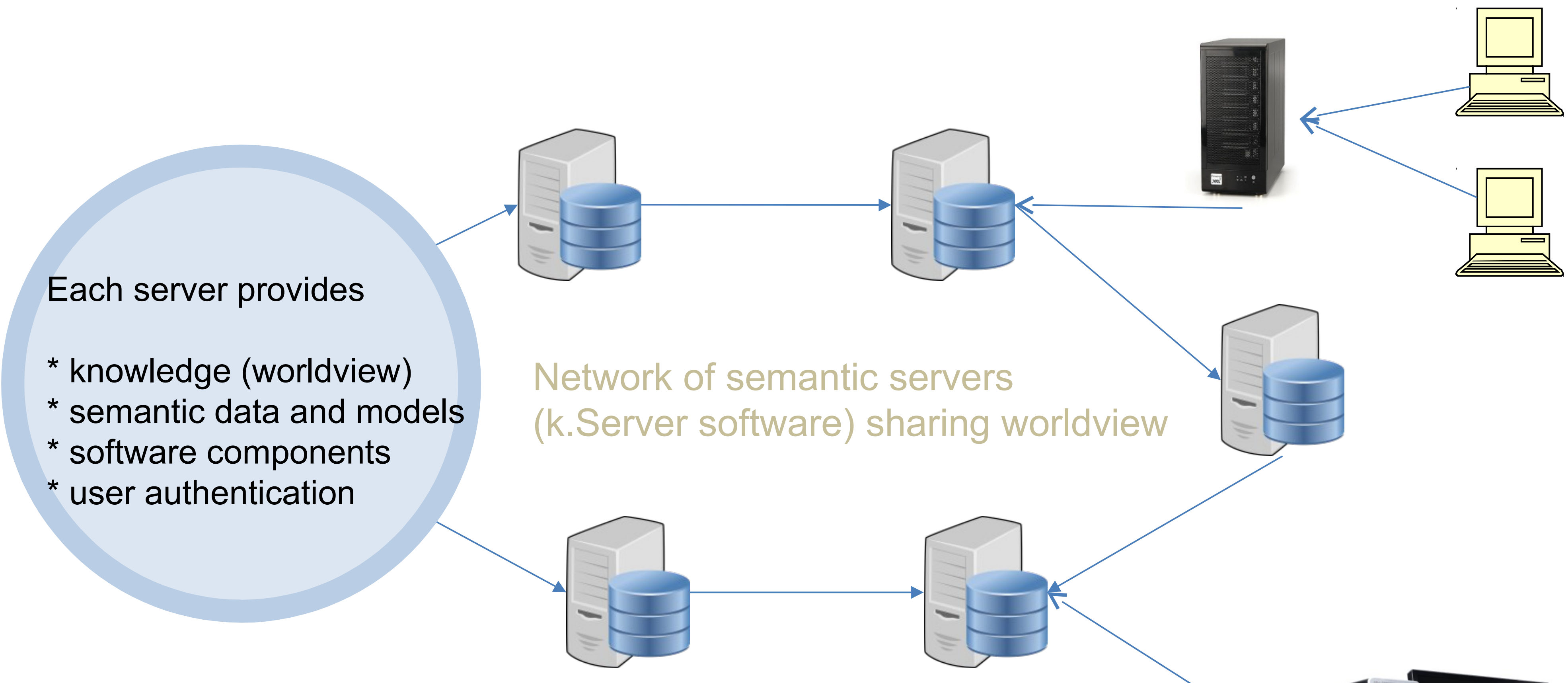
Beneficiaries (e.g. farmers, coastal dwellers) are identified next.

Models and data live on an expanding semantic web

An extensible network hosts data, models and model services available to users



Tooling: distributed semantic web infrastructure



Web users connect to modeling engine and use web interface for modeling

UI is drag-and-drop only, optimized for non-technical user

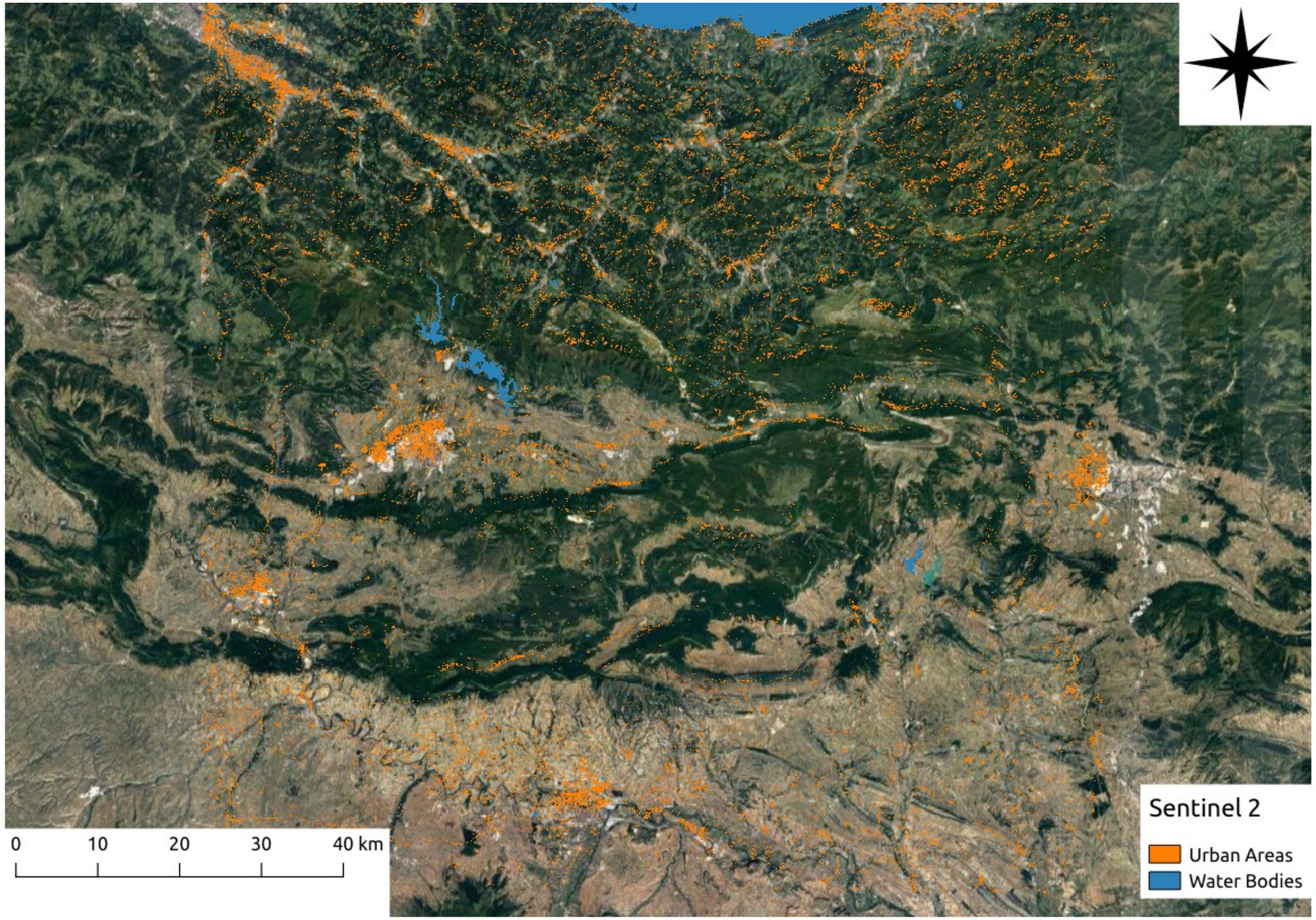
Modelers have a private engine and connect to the network using the modeling IDE

UI is optimized for developers and modelers

Modeling engines
- resolve user queries into working models
- find content on the semantic network

Socializing the pixels: putting people on the map

- *People and Pixels: Linking Remote Sensing and Social Science (1998)*
- Characterizing ES Beneficiaries: where they are, who they are, how they access which ES originated where…
- Context-dependent strategy, built by AI according to availability of data and models in each segment
- Remote Sensing data are coupled with other info to build maps from which to classify or extract agents
- Example: Sentinel 2 (March 10th 2017, Bizkaia, Spain)
    - Combination of Green and Near Infrared bands
    - Water bodies
    - Built-up areas
    - 20 meters spatial resolution
    - OSM used to find clusters of agents; pixels help characterize them.

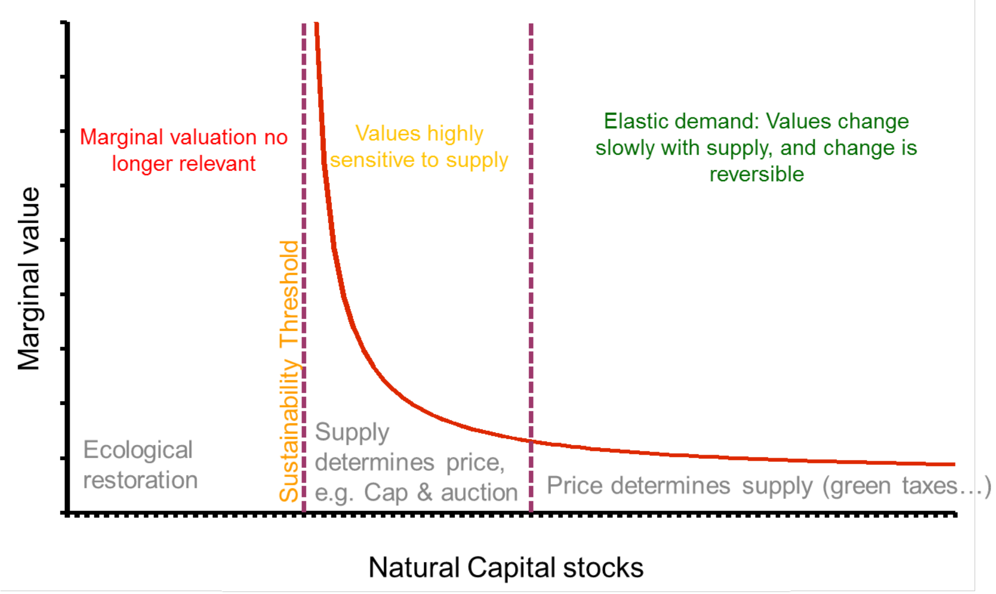


Building social agents: issues and methods

Build agents, not maps

- **Scaling**: agents depend on scale. E.g., at the national scale models may focus on cities; at the regional scale models may need to see households.
  - Within an agent paradigm, this choice can be automated
- **Identity**: given natural features (i.e. ecosystem extent and condition), establish the likely ES demand and supply, i.e. which ecological and social agents types are involved
- With these issues addressed, social agents can be characterized by either
  - Feature extraction from dependency or probability maps
  - Classification of demand for previously mapped agents

Characterizing social agents

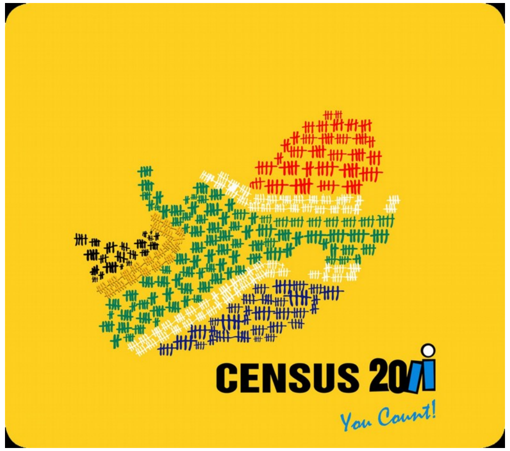


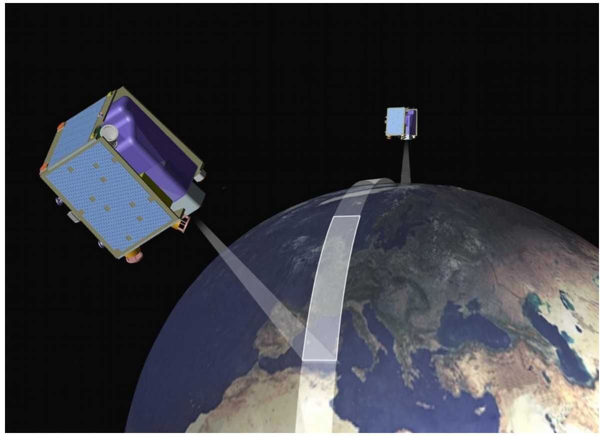
- Demand or need?
  - Supply vs. Demand analysis
  - Substitutability vs. Value
- Characterization
  - Basic needs (→ focus on water/food/energy) vs. non-essential (e.g. recreation)
  - Net producers or importers of ES (red/green loops)
    - Key point: analyzing access to institutions (market vs subsistence)
- Methods
  - Semantics first!
  - Machine learning + remote sensing; use ALL data (including crowdsourced information) at their appropriate scales

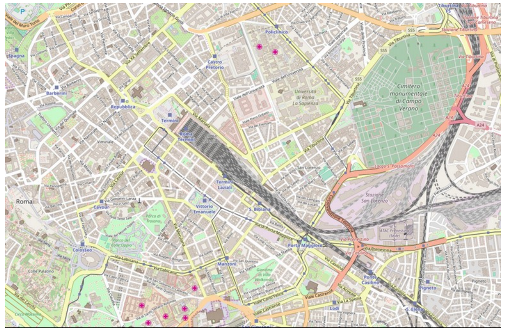
Data Sources

Multiple data sources need to be integrated to respond to multidimensional problems

1) National Census, HH Survey, PRA
2) Remote Sensing (satellites + drones)
3) Crowd Sourced Information (Voluntary)
4) BIG data (e.g. mobile phone cells, social networks, etc.)







Methods: help can come from AI

- Semantics: “data labelling and matching system, that allows us to accurately harmonize data inputs, outputs, and model components which a computer can assembly to respond to a query”

- Machine Learning

Category	Task	Common algorithms
Unsupervised learning (learning without feedback from a trainer)	Clustering	k-means
	Associations	Apriori
	Dimensionality reduction	PCA
Supervised learning (learning past actions/decisions with trainer)	Classification (learning a categorical variable)	Bayesian Networks, Decision Trees, Neural Networks
	Regression (learning a continuous variable)	Linear Regression, Perceptron

Machine learning cross validation results on training set

Correctly Classified Instances	94	91.2621 %
Incorrectly Classified Instances	9	8.7379 %
Kappa statistic	0.8202	
Mean absolute error	0.0334	
Root mean squared error	0.1132	
Relative absolute error	30.049 %	
Root relative squared error	49.3575 %	
Total Number of Instances	103