IM in a nutshell

The underlying vision: shared, distributed, collaborative models

SEMANTICS for data and models

- Core concepts: **subjects**, qualities, processes, events, relationships…
- Domain ontologies for socio-environmental systems, land cover; integration with vocabularies

APPLICATIONS

- Ecosystem services assessment (ARIES)
- Food and other environmental securities (ASSETS)
- Integrating hydrology, primary production, nutrients with agent models to best represent SSE.

OPEN SOURCE SOFTWARE

- User-end (modelers and end users)
- Cloud technology (institutions)

COLLABORATIVE MODELING

- Interoperable data and models
- Independent development of coordinating components
- International Spring University since 2013

INTEGRATED MODELING INFRASTRUCTURE

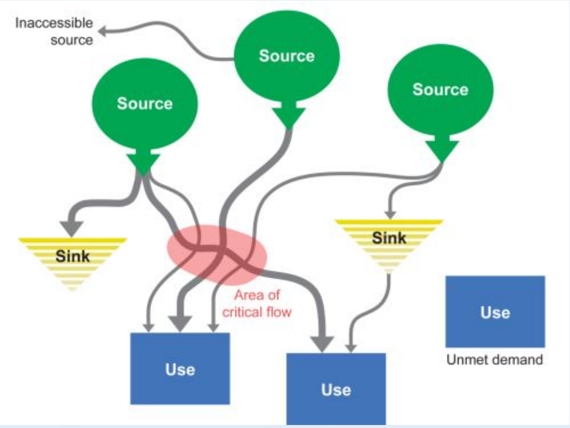
- Assembly of models from networked data and model components
- Accurate coupled human-natural system representations

The first decade of ARIES: redefining the narrative and the tools

The science

A revised ES narrative:
- Flows, not stocks
- Explicit uncertainty
- *System to indicators* – not vice-versa
- ES as network of agents

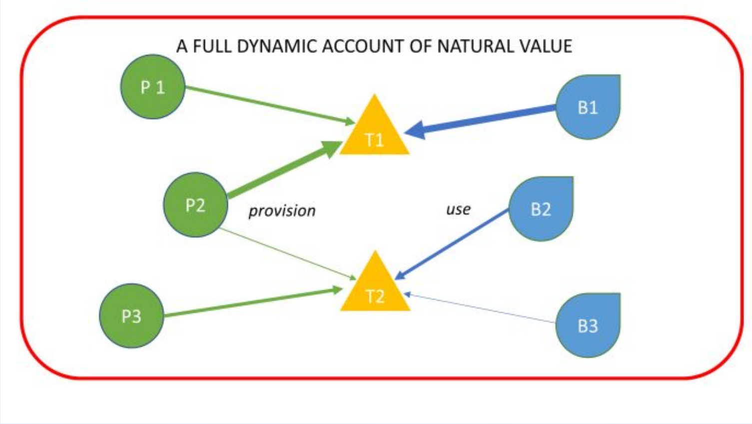
Using:
- Machine learning (Bayesian and beyond)
- Multi-paradigm models
- ES flow dynamics



The technology

Outsourcing complex modeling tasks to artificial intelligence:

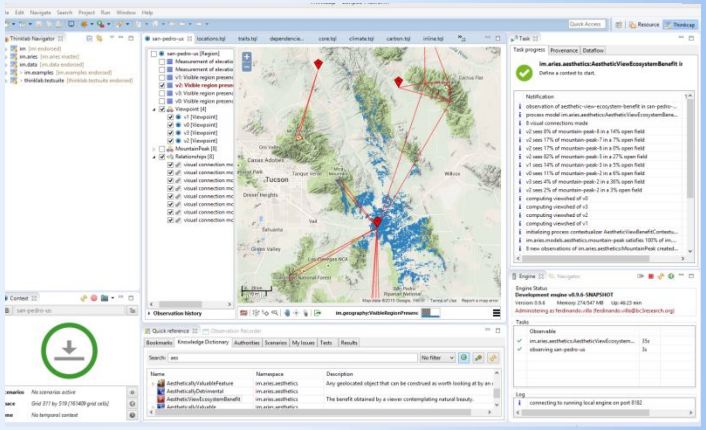
- Integrated modular modeling,
- Build adaptive models from components
- Choose best data/models for the context
- Collaborative development
- Distributed execution



The community

It's not "our model" but your models:

- Web-based data
- Web-based model components
- Collaborative modeling
- Open source software
- Yearly modeling school
- A web-based use paradigm



2007 National Science Foundation → 2017

A roadmap for ARIES: covering the full arch of ES assessment needs

Supply/Use/Balance models
optimized for NCA and comparability

- No input needed
- Easily customized
- Arbitrary resolutions
- Adaptive modeling
- Consistent outputs
- MCA for trade-offs
- Automated reporting

Remote sensing-driven models
the most current information

- Responsive and current
- Machine learning to “socialize the pixels”
- Using volunteered information
- Fine resolution based on Sentinel/Copernicus/Landsat
- Automatic re-evaluation
- Archiving and change tracking

Agent-based models
providers, beneficiaries, transactors

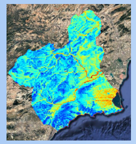
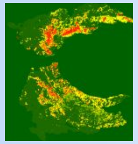
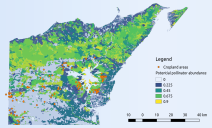
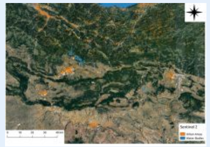
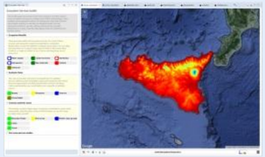
- Automatic switch at smaller scales
- Track individual agents and their interactions
- Compute individual flow paths
- Scenario analysis including dynamic factors and events

Coarser temporal/spatial scale

Fine scale, higher detail, dynamics

AI-assisted, unchanging complexity for the user: toolset includes web-based explorer and modeler UI

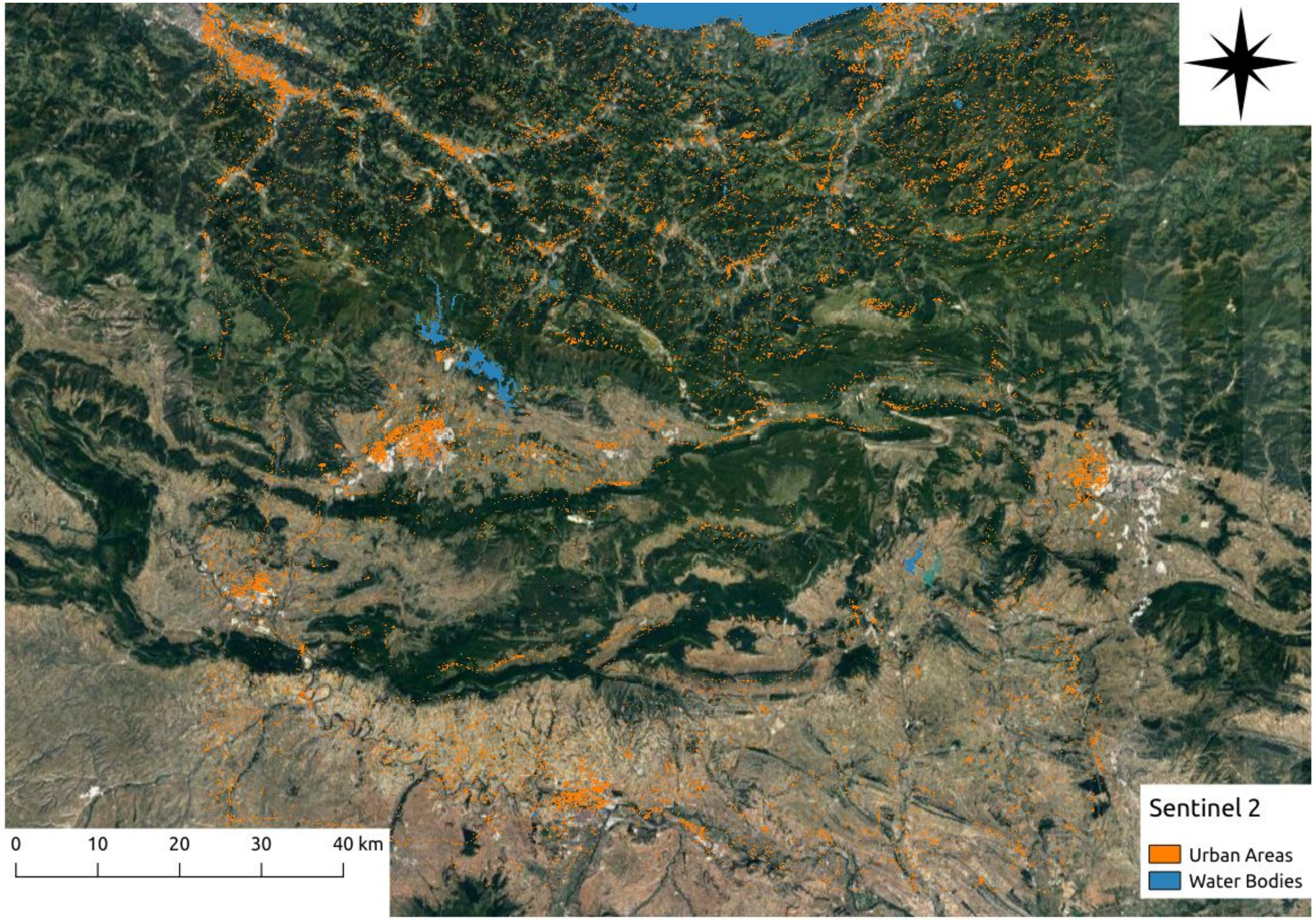
Rapid assessment (no input) -> Use own data -> Choose scenarios -> Develop scenarios -> Tradeoff analysis -> Dynamic prediction


IM gets “social”

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.

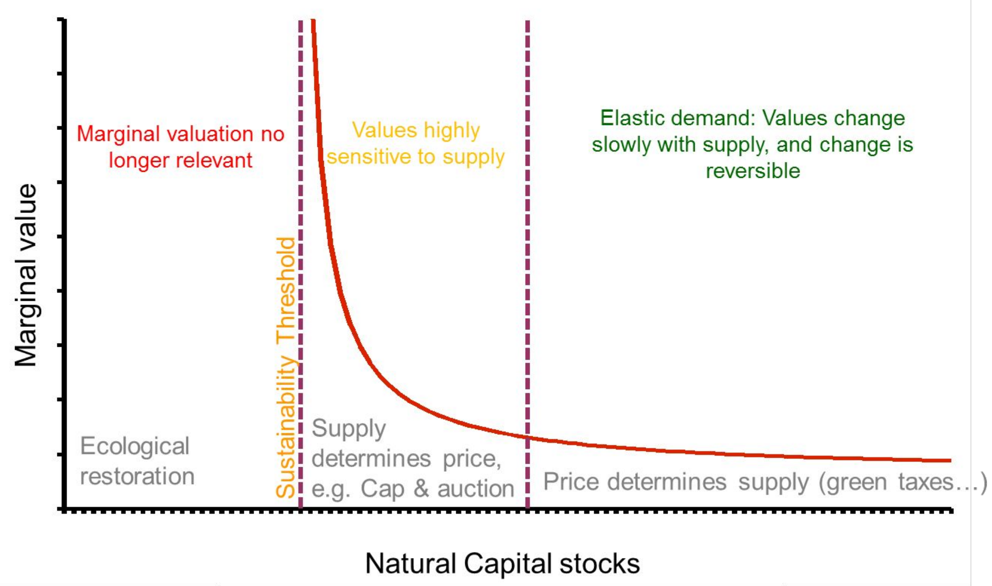


Building social agents: issues and methods

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

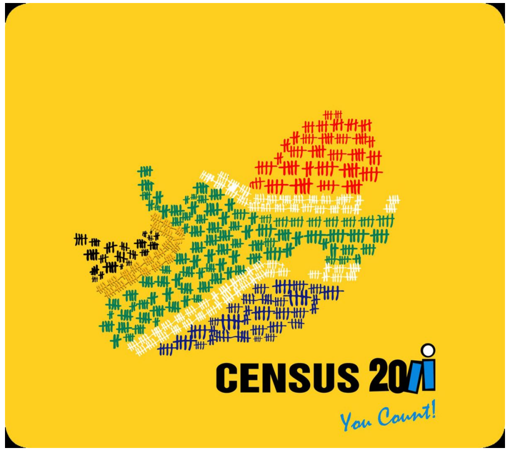


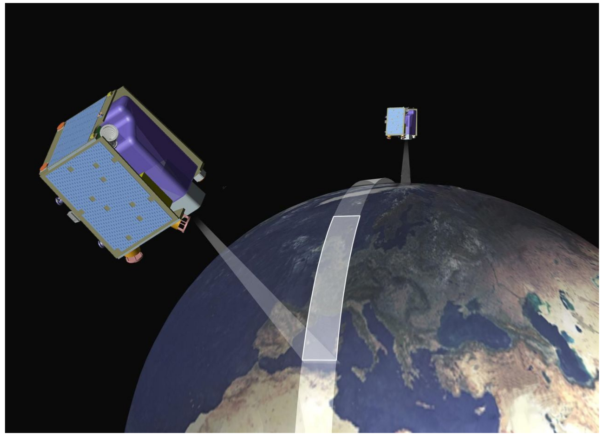
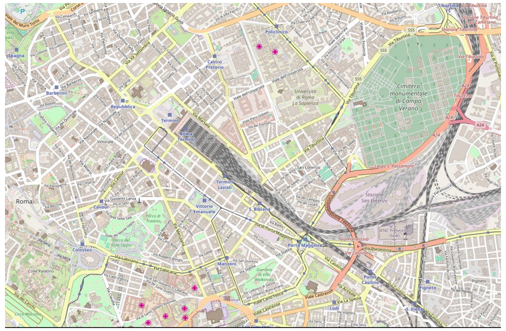
- Demand or need?
  - Supply vs. Demand analysis
  - Substitutability vs. Value
- Characterization
  - Basic needs (→ focus on water/food/energy) vs. non-essential (e.g. recreation)
  - Net producers or importers of ES (red/green loops)
    - Key point: analyzing access to institutions (market vs subsistence)
- 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.)



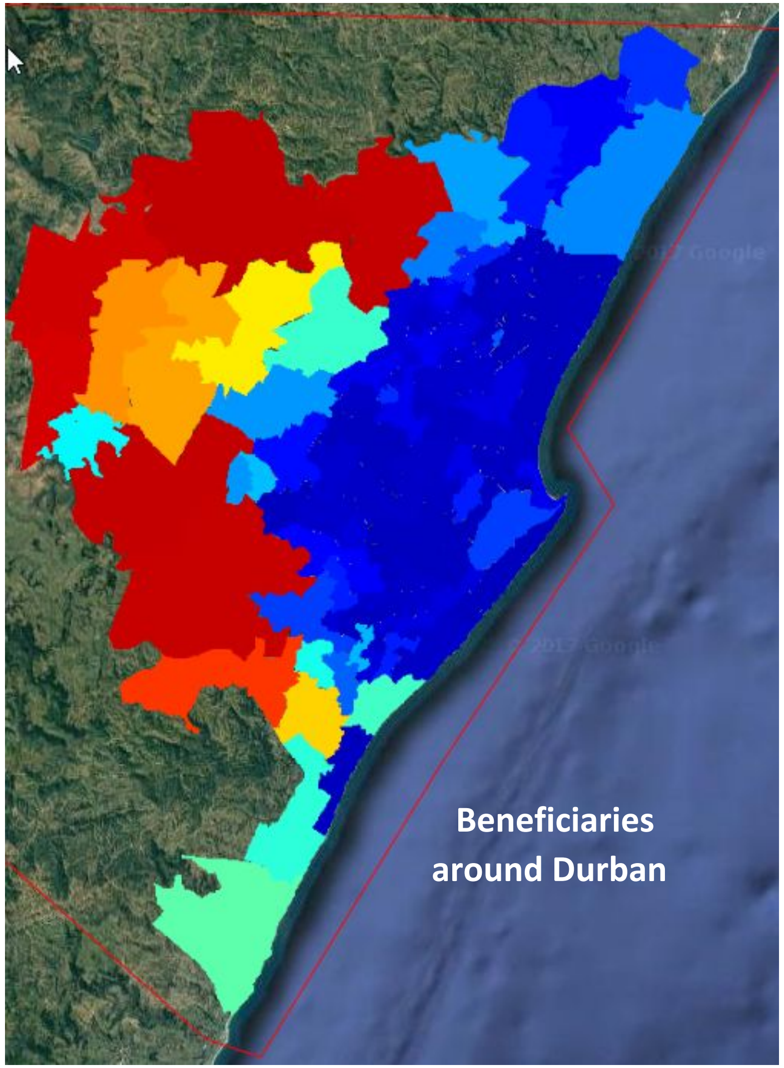

Methods: help can come from AI

- 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

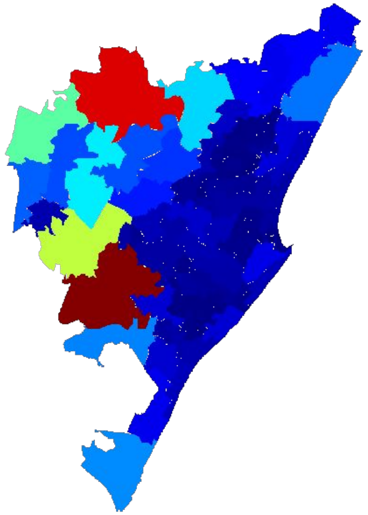
Category	Task	Common algorithms
Unsupervised learning (learning without feedback from a trainer)	Clustering	k-means
	Associations	Apriori
	Dimensionality reduction	PCA
Supervised learning (learning past actions/decisions with trainer)	Classification (learning a categorical variable)	Bayesian Networks,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

Machine learning cross validation results on training set

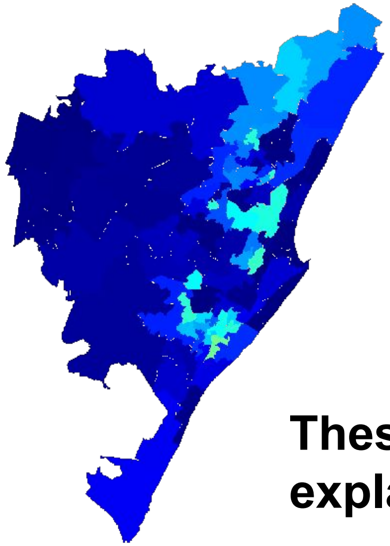
Correctly Classified Instances	94	91.2621 %
Incorrectly Classified Instances	9	8.7379 %
Kappa statistic	0.8202	
Mean absolute error	0.0334	
Root mean squared error	0.1132	
Relative absolute error	30.049 %	
Root relative squared error	49.3575 %	
• Total Number of Instances	103	



LandPerHH

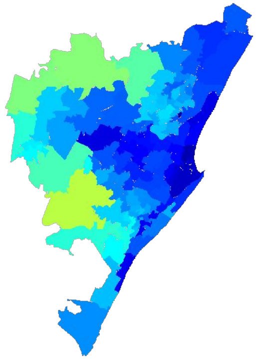


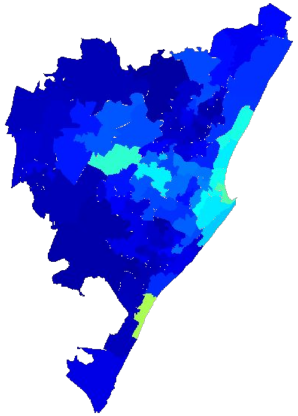
InformalHH



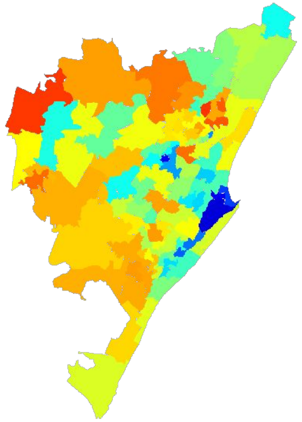
These 2 explain 80%

LargeHH (>4)

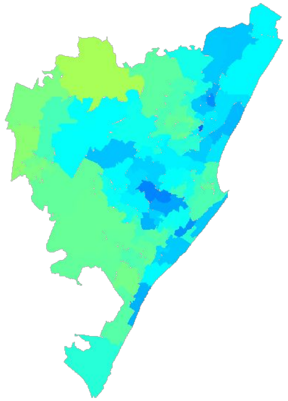




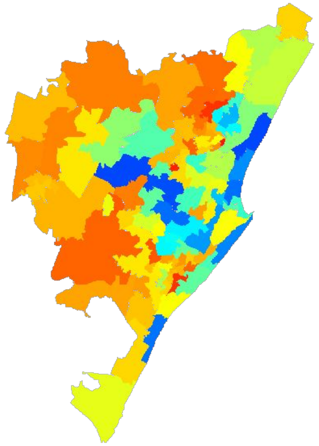
Immigrants



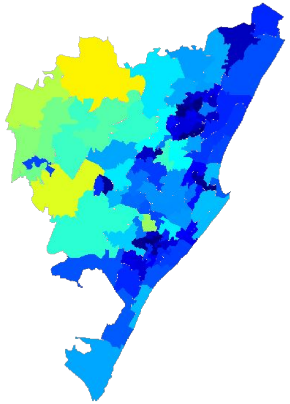
House owning



FemaleHead



Poverty



MOSS

Other applications (1): Human Migration

Moving2Adapt Step-by-Step

1. **Semantic integration** of the available knowledge on environmental migration (data and models).
2. **Machine learning** to define clusters of *migratory profiles* (migrant-origin-transit-destination).
3. **Global ABM** of integrated social-ecological systems (climate-ecosystems-demography-economics).
4. **Ensemble simulations** of global migration patterns into the future (spatially and temporally explicit).
5. **Analysis of adaptation measures** in identified origin and destination hotspots (with stakeholders).

Migratory profile: a migrant behavioural type characterized by a certain typology of socio-economic profile and livelihood behaviour, with a certain type of origin location, migratory behaviour (e.g. voluntary vs. forced, proactive vs. reactive, permanent vs. seasonal vs. circular), transit trajectory, and preferred destination.

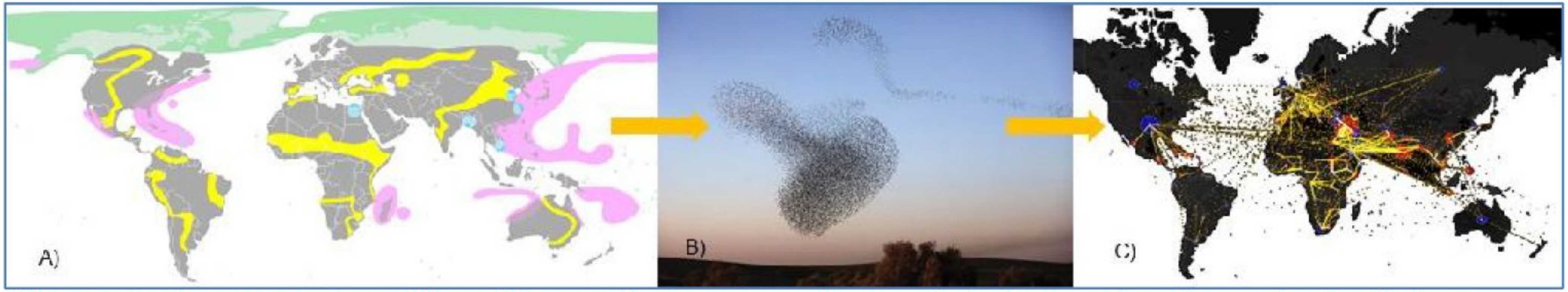


Figure 1. *From mapping vulnerable populations to exploring global migration flows via simulation.*

Other applications (2): SDG Monitoring

- Various types of data and models are needed to project the consequences of climate change and unsustainable management on:
  - Earth System components (vegetation, water, soils, air, biochemical cycles, etc.), and
  - Socio-economic aspects (agricultural production, human water management, international trade, food security, etc.)
- Holistic and integrated modelling is necessary to address the complex interconnections embedded in the SDGs while it’s clear that a “one model fits all” approach will not work.

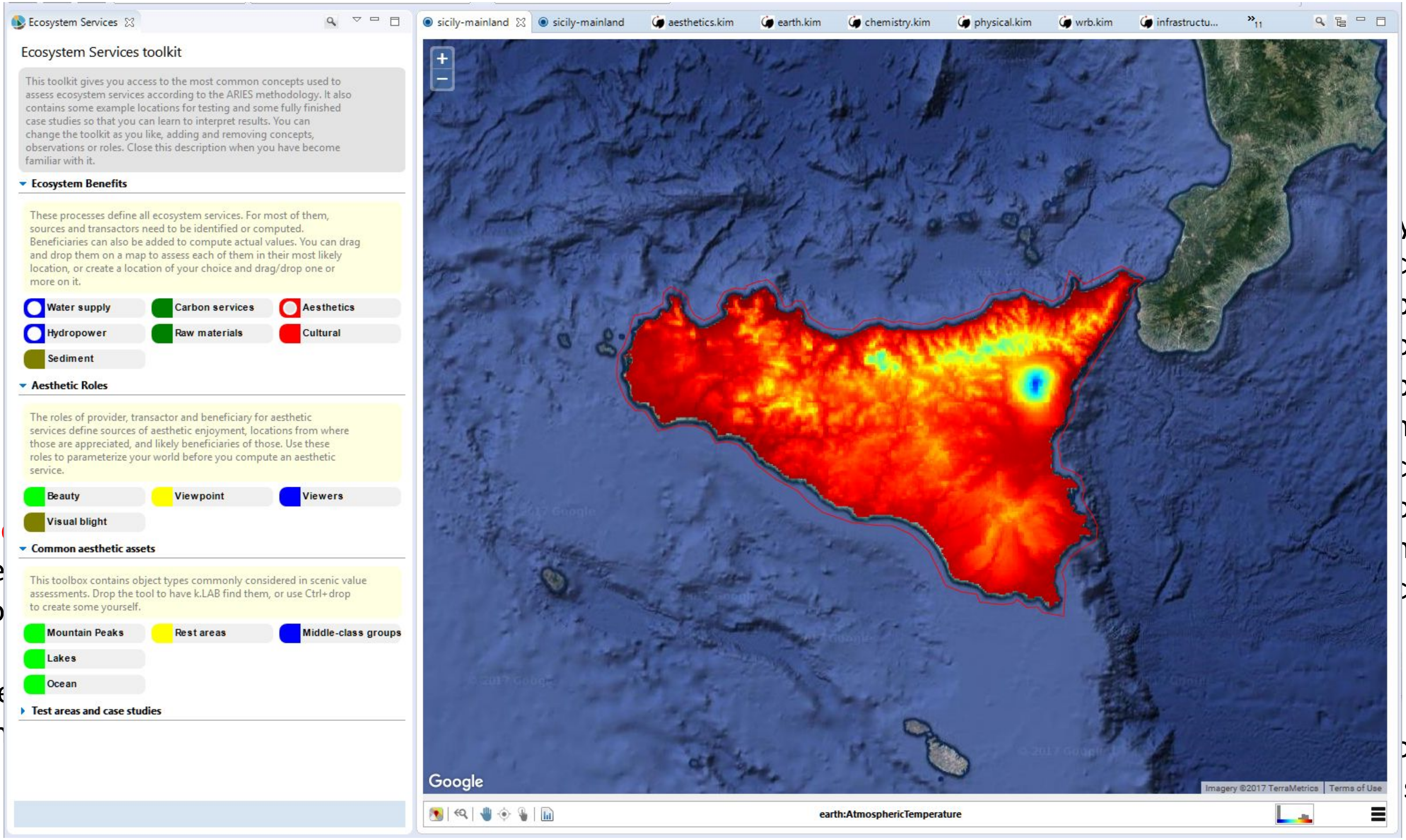
Other applications (3): Environmental Threat Sensor

- Interview environmental defenders on possible drivers of violence against them
- Build a database of key variables – such as deforestation rate, allocation of land concessions, development of major infrastructure, indigenous areas, corruption indices, local and national homicide rate, etc.
- Mine data for a comprehensive study of violence against environmental defenders
- Train a predictive model from data to build a global map of risk, with automatic updates as new data come in
- Public API for applications to use the data as they see fit
- Web interface to catalyse attention and enable volunteer data contributions

N1M
NOT ONE MORE

The user side: a two-step assessment

Client software (desktop & soon web-based) allow modeling with minimal configuration and training. Provenance info is compiled into user documentation for each result set.



Drag-and-drop paradigm for end users

“Palette” of ES tools can store finished studies and scenario results

Models are built and computed when user drops the concept

Full reports are built to document the computation

ystem creates agents and processes from ontological specs builds best-case model out of components and data on the semantic network computes it…

gged into network secure certificate

St

Se

co

(se

or