TOOLS FOR MODELING ECOSYSTEM SERVICES

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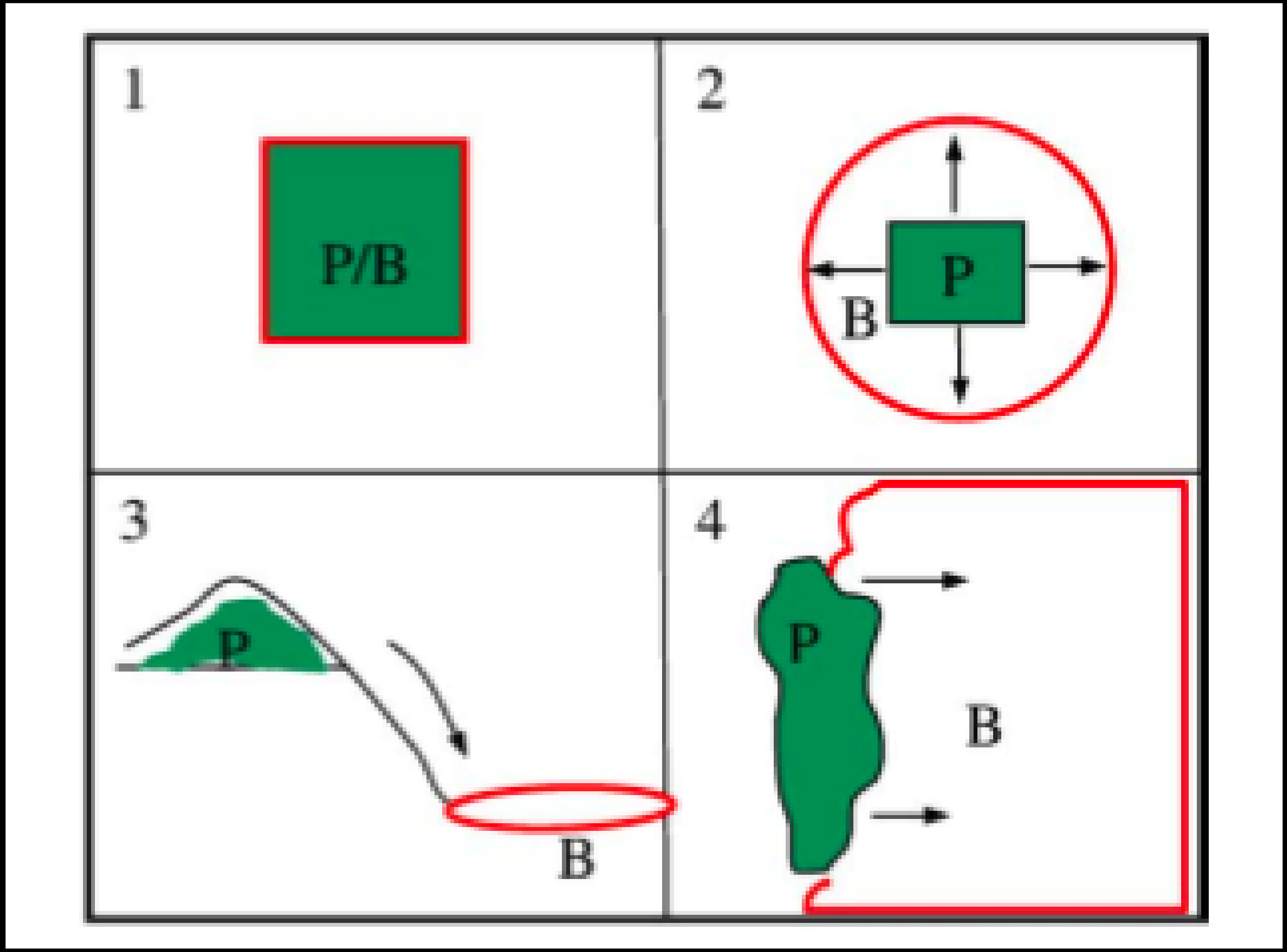
Pretoria

October 2019

Fundamental questions for modeling services flows

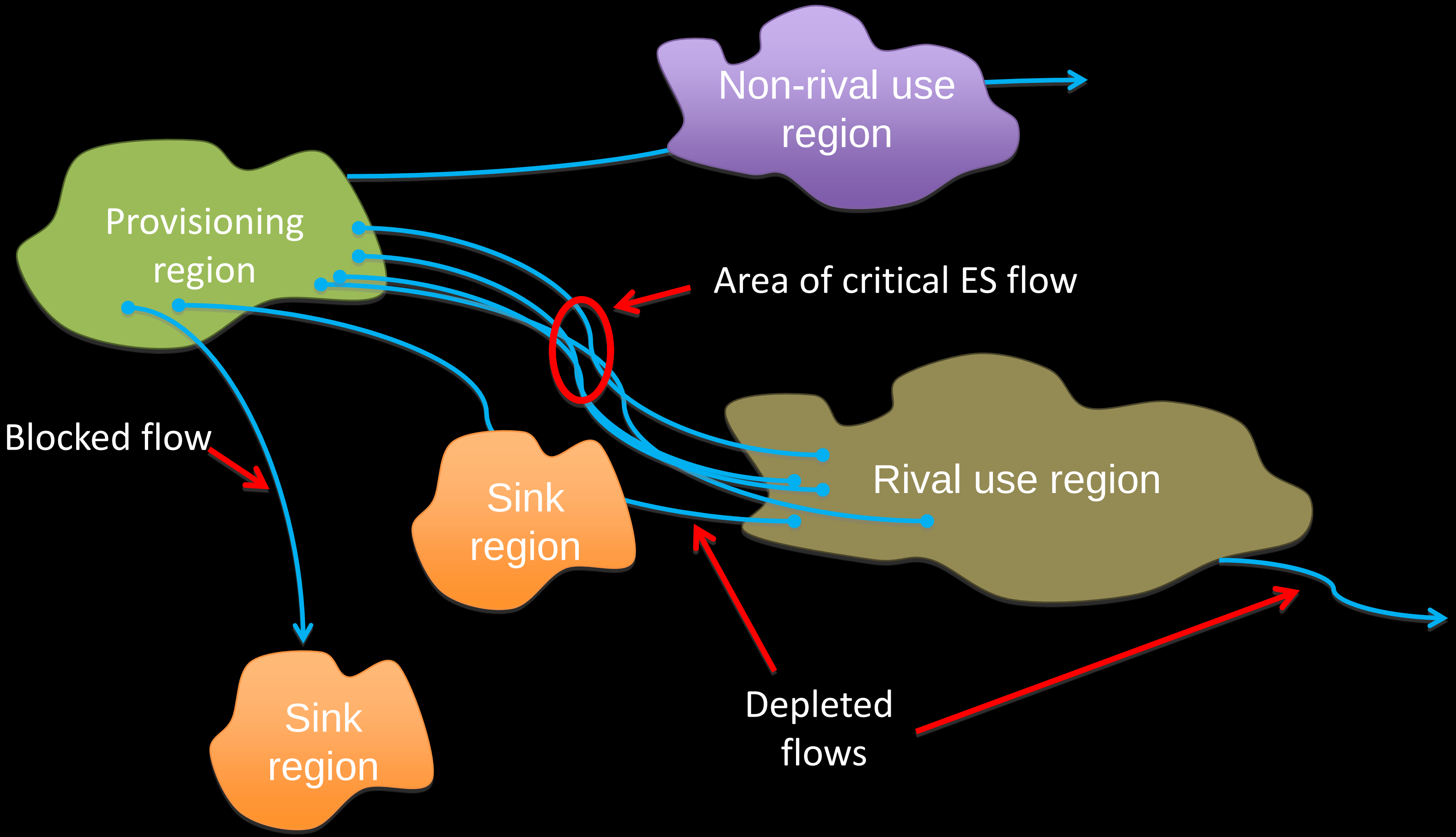
- Where are the ecosystems?
- Where are the beneficiaries?
- How do benefits move from ecosystems to beneficiaries?
- What is the quantity and value of the service?

Spatial context of service flows



Fisher eta l. 2009

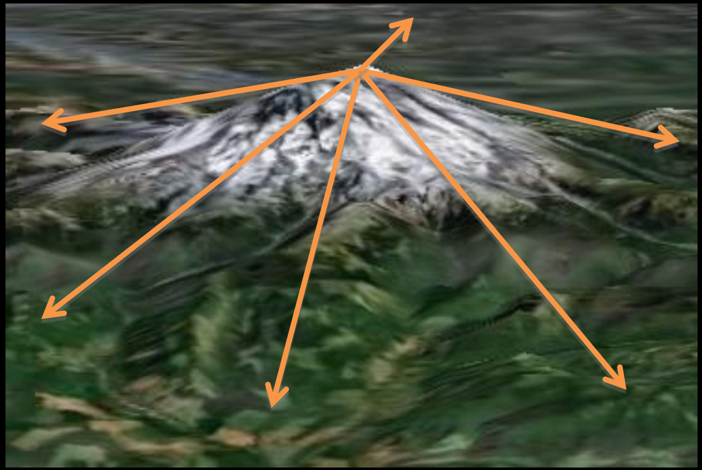
Spatial context of service flows (cont.)



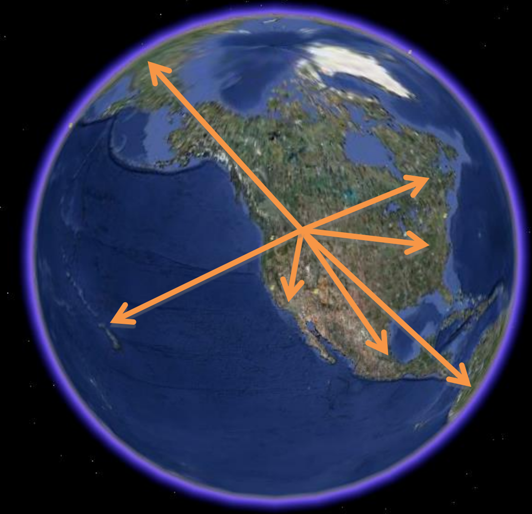
Types of service flows

Hydrologic services

Aesthetic viewsheds



Carbon sequestration, some cultural values



Recreation, flood regulation, coastal protection

Recreation, aesthetic proximity, some cultural services

IUCN

Tools for measuring, modelling, and valuing ecosystem services

Guidance for Key Biodiversity Areas, natural World Heritage sites, and protected areas

Rachel A. Neugarten, Penny F. Langhammer, Elena Osipova, Kenneth J. Bagstad, Nirmal Bhagabati, Stuart H. M. Butchart, Nigel Dudley, Vittoria Elliott, Leah R. Gerber, Claudia Gutierrez Arrellano, Kasandra-Zoica Ivanić, Marianne Kettunen, Lisa Mandle, Jennifer C. Merriman, Mark Mulligan, Kelvin S.-H. Peh, Ciara Raudsepp-Hearne, Darius J. Semmens, Sue Stolton and Simon Willcock

SNAPP
WCPA World Commission on Protected Areas
ASU Center for Biodiversity Outcomes
Arizona State University
Convention on Biological Diversity
BfN Federal Agency for Nature Conservation

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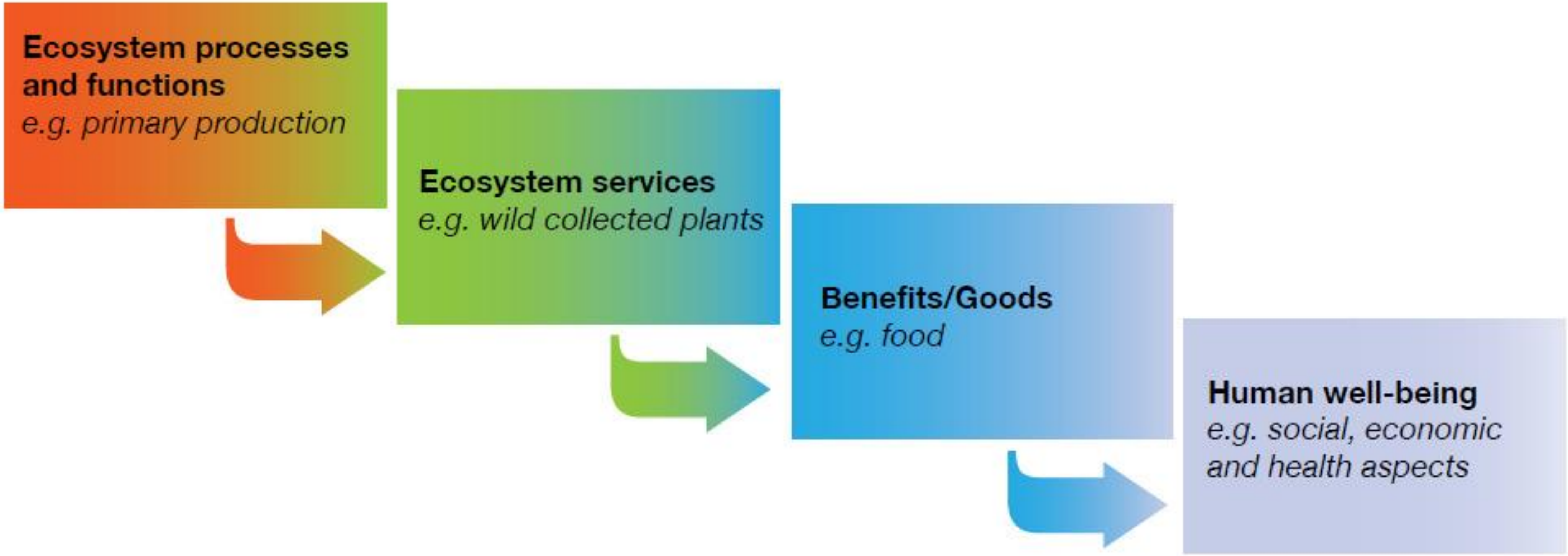
WHAT ARE ECOSYSTEM SERVICES?



Adapted from Haines-Young and Potschin (2010)

WHICH TOOL TO USE?

ECOSYSTEM SERVICES TOOLKIT

tessa

WaterWorld

Co$ting Nature

InVEST
integrated valuation of ecosystem services and tradeoffs

ARIES
ARtificial Intelligence for Ecosystem Services

SolVES
Social Values for Ecosystem Services

mimes

The Protected Areas Benefits Assessment Tool

PROTECTED AREA BENEFITS ASSESSMENT TOOL (PA-BAT)

http://wwf.panda.org/our_work/biodiversity/protected_areas/arguments_for_protection/

The Protected Areas Benefits Assessment Tool

- Free (PDF guide)
- Stakeholder workshop required for each site
- No computer modeling / GIS required
- Non-spatial

- Qualitative
- Site scale
- Adaptable

Ecosystem Services:
(Any)
Examples include:

- Subsistence fisheries
- Fuelwood
- Harvested wild goods
- Hunting
- Livestock grazing

- Medicinal resources
- Traditional agriculture
- Timber
- Water
- Carbon storage
- Coastal protection
- Flood protection
- Cultural or historical values

- Mental & physical health
- Peace & stability
- Research / knowledge
- Education
- Recreation
- Spiritual values
- Scenic quality
- Wilderness and iconic values

EXAMPLE

Economic benefits from 58 PAs in the Dinaric Arc region

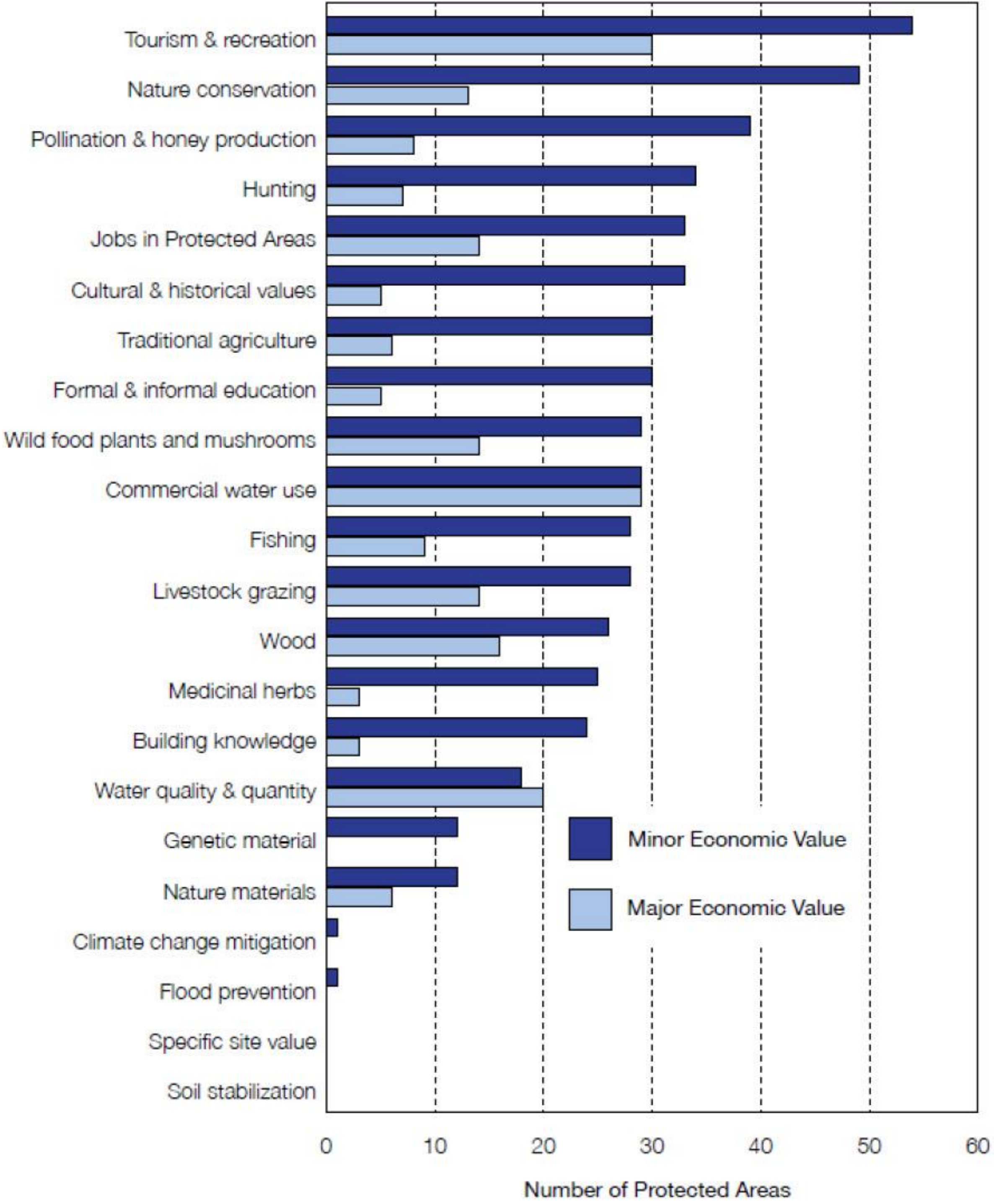
Question: What are the major economic benefits from protected areas?

Why PA-BAT?

Site-level assessment tool, no data required, relatively rapid, workshop-based, no modeling/GIS required

Constraints: Not practical to apply to multiple sites simultaneously, requires workshop(s) for every site, local knowledge may be limited or biased

The Protected Areas Benefits Assessment Tool



TESSA: TOOLKIT FOR ECOSYSTEM SERVICE SITE-BASED ASSESSMENT

http://tessa.tools/

- Free (PDF guide)
- Minimal expertise required
- Moderate time required
- Requires field data collection
- Non-spatial
- Quantitative
- Monetary
- Site scale
- Comparative

Ecosystem Services:

1. Global climate regulation
2. Harvested wild goods
3. Cultivated goods
4. Water (provision, quality)
5. Nature-based recreation
6. Cultural (forthcoming)
7. Pollination (forthcoming)
8. Coastal protection (forthcoming)

EXAMPLE

Economic valuation of Moeyungyi Wetland

Question: What is the value of ecosystem services provided by a KBA, and how would the value change under an alternative scenario?

Why TESSA?

Site-level assessment tool, comparative, provides results in monetary terms, relatively rapid, no ES expertise required

Constraints: Not practical to apply to multiple sites simultaneously, or at the national scale

tessa

ECONOMIC VALUATION OF MOEYUNGYI WETLAND, MYANMAR

Prepared by Kelvin S.-H. Peh, Jennifer C. Merriman, Thiri Dae We Aung, Saw Mon Theint, Natsuki Murata, Keiko Suzue

Report submitted to the Ministry of Environment, Japan

Ministry of the Environment

BirdLife INTERNATIONAL

BANCA

CO$TING NATURE & WATERWORLD

http://www.policysupport.org/costingnature
http://www.policysupport.org/waterworld

- Free (basic) or paid (advanced)
- No expertise required
- Least time required
- No data required

- Spatial
- Quantitative
- Non-monetary
- Site to global scale
- Scenarios

Ecosystem Services:

1. Carbon
2. Freshwater (quantity, quality, flow regulation)
3. Hazard mitigation
4. Nature tourism

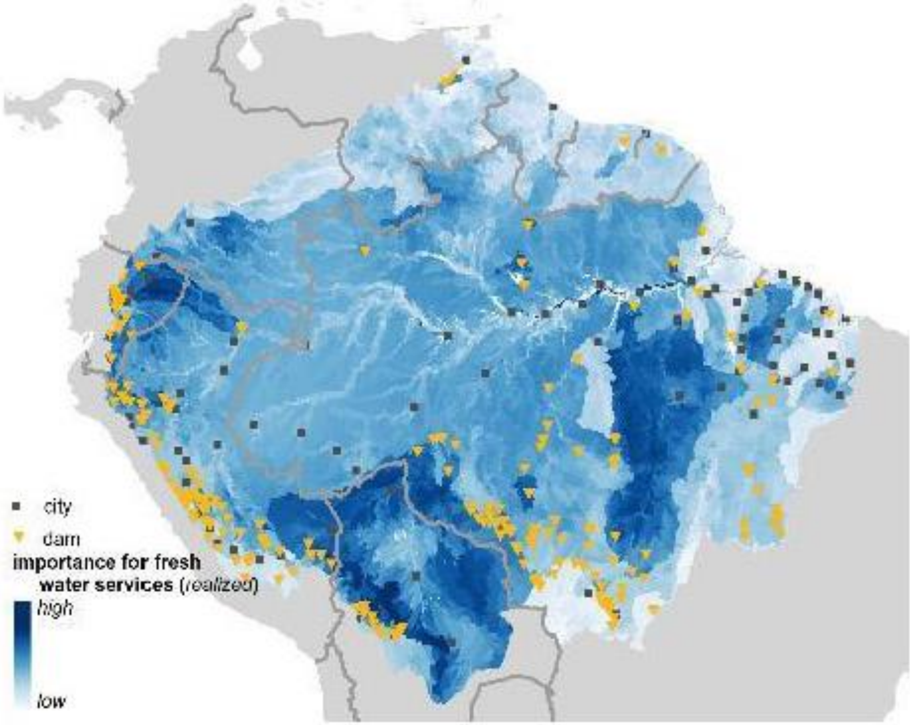
EXAMPLE

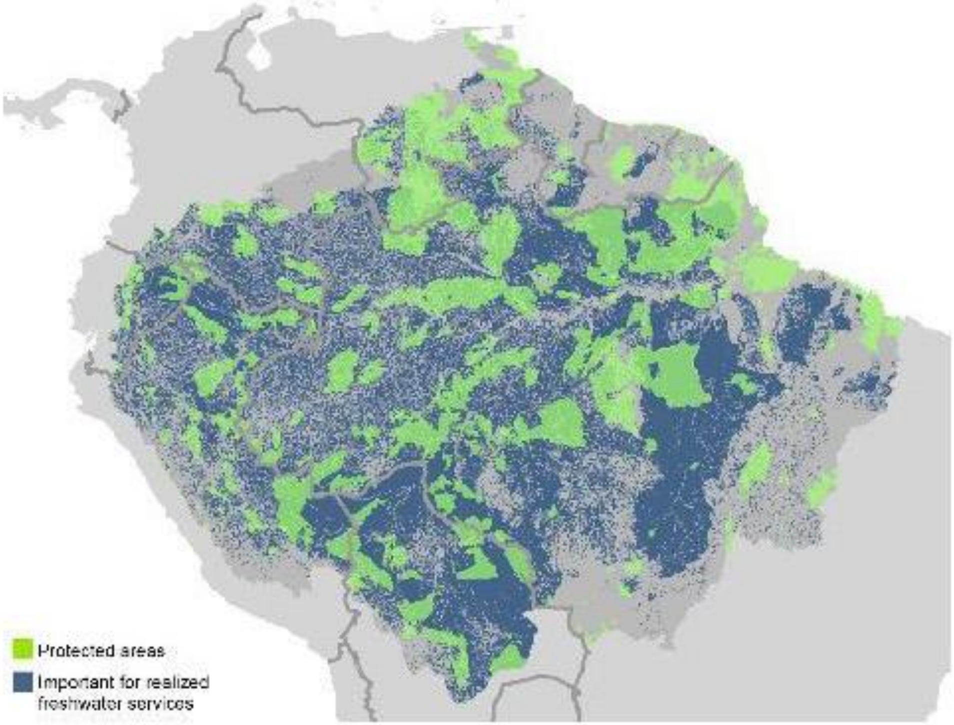
Regional-scale analysis of freshwater services provided by PAs

Question: what is the total contribution of PAs to freshwater services in Amazonia?

Why WaterWorld? Rapid, all required data provided

Constraints: not open-source, uncertainty related to accuracy of global data





INVEST: INTEGRATED VALUATION OF ECOSYSTEM SERVICES AND TRADEOFFS

InVEST
integrated valuation of ecosystem services and tradeoffs

www.naturalcapitalproject.org/invest/

- Free
- Open-source
- Requires a GIS
- Moderate time required
- Requires data (for example, land cover)
- Spatial (maps)
- Quantitative
- Non-monetary or monetary
- Multiple scales (local to national)
- Comparative (scenarios)

Ecosystem Services:

1. Carbon
2. Coastal blue carbon
3. Coastal vulnerability
4. Fisheries
5. Habitat quality
6. Habitat risk assessment
7. Marine fish aquaculture
8. Marine water quality
9. Nearshore waves and erosion
10. Offshore wind energy
11. Recreation
12. Water yield (hydropower production)
13. Scenic quality
14. Sediment retention
15. Water purification
16. Wave energy

EXAMPLE

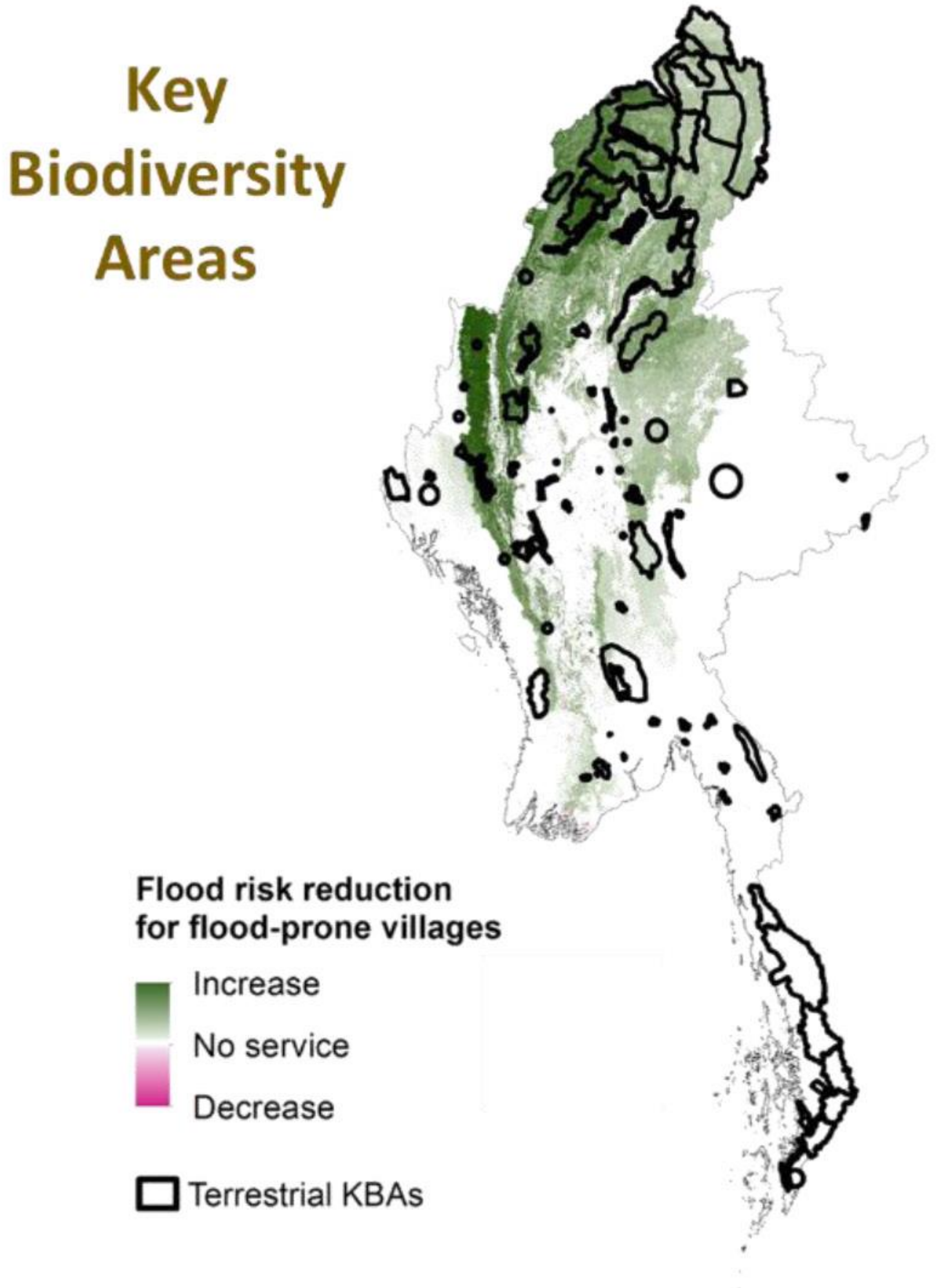
National scale ecosystem service modeling

Question: How are KBAs benefitting people in Myanmar at a national scale?

Why InVEST?

National-scale, relatively low data requirements

Constraints: modeling based on limited data & assumptions, requires GIS expertise



InVEST
integrated valuation of ecosystem services and tradeoffs

ARTIFICIAL INTELLIGENCE FOR ECOSYSTEM SERVICES (ARIES)

ARIES
ARtificial Intelligence
for Ecosystem Services

http://aries.integratedmodelling.org/

- Free (k.LAB software) & open-source
- Currently: specialized expertise / training required
- Future: web-interface (no expertise required)
- New case studies: all data required

- Global models: no data required
- Spatial
- Qualitative or quantitative
- Monetary or non-monetary
- Site to global scale
- Cloud-based
- Collaborative
- Context-specific

Ecosystem Services (global models - can be run anywhere):

1. Carbon storage
2. Flood regulation
3. Pollination
4. Recreation
5. Sediment regulation

In development:

1. Coastal flood regulation
2. Landslide regulation
3. Mariculture
4. Water supply

Case studies (cannot be run anywhere):

1. Aesthetics/scenic quality
2. Biodiversity
3. Carbon sequestration
4. Crop production
5. Cultural/spiritual values
6. Fisheries

SOCIAL VALUES FOR ECOSYSTEM SERVICES (SOLVES)

https://solves.cr.usgs.gov/

SolVES
Social Values for Ecosystem Services

- Free
- Spatial mapping of social values
- Requires ArcGIS
- Requires social surveys / social science expertise
- Can be used to assess values of diverse stakeholder groups
- Quantitative 10-point social values metric
- Values Transfer Tool
- Can be combined with biophysical modeling tools

Ecosystem Services

- Any social or cultural values

Examples include:

- Cultural or historical values
- Cultural heritage
- Inspiration, creative or artistic
- Social relations
- Community benefits
- Research / knowledge benefits
- Recreation, nature tourism
- Scenic quality / aesthic viewsheds
- Wilderness and iconic values
- Etc.


PAUSE FOR QUESTIONS

IUCN

Tools for measuring, modelling, and valuing ecosystem services

Guidance for Key Biodiversity Areas, natural World Heritage sites, and protected areas

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Craig Groves, Series Editor

https://portals.iucn.org/library/node/47778

Comparison of ecosystem services tools

4

Pages 11-25

TOOL REVIEW

Name	Acronym
Integrated Valuation of Ecosystem Services and Tradeoffs	InVEST
Toolkit for Ecosystem Service Site-based Assessment	TESSA
Co$ting Nature	C$N
Artificial Intelligence for Ecosystem Services	ARIES
Social Values for Ecosystem Services	SolVES
Multiscale Integrated Models of Ecosystem Services	MIMES
Protected Areas Benefits Assessment Tool	PA-BAT
Ecosystem Services Toolkit	EST
WaterWorld	WW

InVEST
integrated valuation of ecosystem services and tradeoffs

tessa

Co$ting Nature

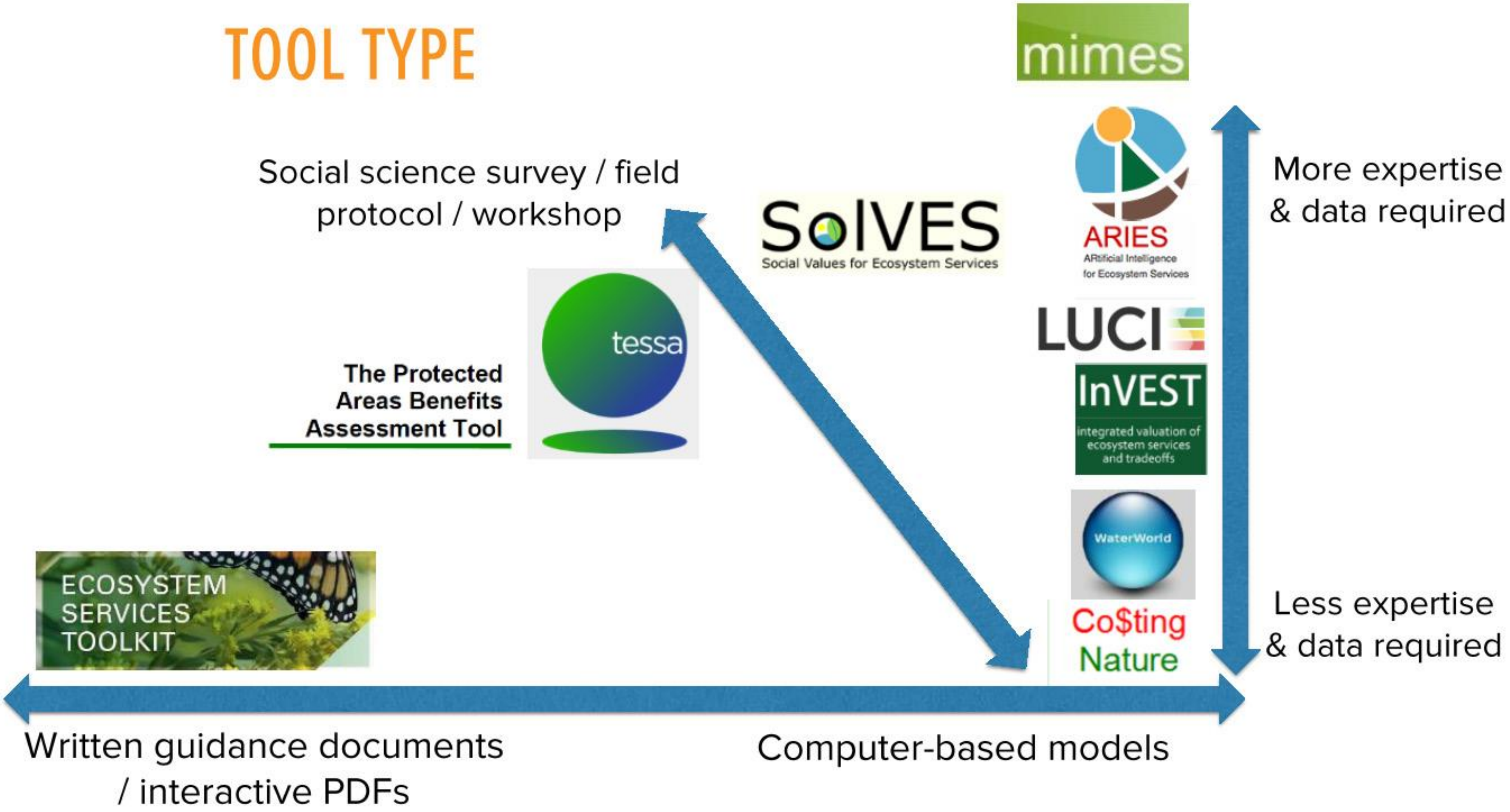
ARIES
ARtificial Intelligence for Ecosystem Services

SolVES
Social Values for Ecosystem Services

mimes

The Protected Areas Benefits Assessment Tool

TOOL TYPE


mimes
Social science survey / field protocol / workshop
SolVES
Social Values for Ecosystem Services
ARIES
ARtificial Intelligence for Ecosystem Services
More expertise & data required
The Protected Areas Benefits Assessment Tool
tessa
LUCI
InVEST
integrated valuation of ecosystem services and tradeoffs
WaterWorld
ECOSYSTEM SERVICES TOOLKIT
Co$ting Nature
Less expertise & data required
Written guidance documents / interactive PDFs
Computer-based models

1. Reason for assessment

- Advocacy
- Spatial Planning
- Finance
- Establish a PES scheme

2. Type of outputs needed

- Qualitative / quantitative
- Spatial / non-spatial
- Monetary / non-monetary
- Single site / multi-site

3. Practical considerations

- Time
- $
- Expertise
- Data

InVEST integrated valuation of ecosystem services and tradeoffs

tessa

Co$ting Nature

ARIES ARtificial Intelligence for Ecosystem Services

SolVES Social Values for Ecosystem Services

mimes

LUCI

1. Reason for assessment

Reasons for measuring ES provided by sites	ARIES	C$N	EST	InVEST	MIMES	PA-BAT	SolVES	TESSA	WW
Public/policy support									
Provide additional evidence and justification for the importance of conserving a particular site	✓✓	✓✓	✓	✓✓	✓✓	✓✓	✓	✓✓	✓✓
Foster local awareness of the ES provided by a particular site	✓	✓✓	✓	✓✓	✓✓	✓✓	✓	✓✓	✓✓
Build support for the conservation of multiple sites through increased understanding of their wide range of benefits	✓✓	✓✓	✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓
Link ES contributed by all sites in a country to international or national sustainability goals and national policies (e.g. SDGs)	✓	✓✓		✓✓	✓	✓✓			✓✓
Site management									
Establish the baseline of ES provided by a site to enable monitoring of changes and support management planning	✓✓	✓✓	✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓
Reveal synergies and possible trade-offs between ES and/or ES and conservation objectives to identify management options for the site	✓	✓	✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓
Develop, implement and update management strategies for the site (e.g. integration of ES into site's management plan or developing a business plan for the site)	✓	✓	✓	✓✓	✓✓	✓✓	✓	✓✓	✓
Human well-being									
Ensure a good understanding of the ES values that are important to resident, local and more distant stakeholders	✓✓	✓✓	✓	✓✓	✓✓	✓✓	✓	✓✓	✓✓
Assess compensation options to resident and local stakeholders for ES forgone as a result of biodiversity conservation, to contribute to discussions about Free Prior and Informed Consent, conflict resolution, etc.				✓		✓	✓	✓	✓✓

Table 3

✓ = can potentially be used; ✓✓ = can potentially be used and there are case studies

TYPES OF OUTPUTS NEEDED & PRACTICAL CONSIDERATIONS

1. Do you need results that are **quantitative**?
2. Do you need results to be spatially explicit (**maps**?)
3. Do you need results that are in **monetary units**?
4. Is the assessment for a **single site** or area?
5. Do you need results which are **comparative** (between two sites or policy scenarios?)
6. Do you have capacity / time to **develop the model** yourself?
7. Do you **already have data** on ecosystem services at the relevant scale?
8. Do you have capacity / time for **field data collection**?
9. Do you have capacity / time for **stakeholder consultation** or surveys?

2. Type of outputs needed

Tool	ARIES*	C$N	EST	InVEST	MIMES	PA-BAT	SolVES	TESSA	WW
Type of outputs that can be produced									
Maps of services (GIS based)	✓	✓		✓	✓		✓		✓
Maps of services (participatory mapping)						✓	✓	✓	
Relative or qualitative values	✓	✓	✓	✓	✓	✓	✓	✓	✓
Quantitative (biophysical units)	✓			✓	✓			✓	✓
Monetary value	✓	✓		✓	✓		✓	✓	✓
Designed for scenario comparison (e.g. between land use or policy scenarios)	✓	✓		✓	✓			✓	✓
Time, resources and skills required									
Requires additional paid software licenses					✓		✓		
Requires use of GIS software	✓			✓	✓		✓		
Requires modelling skills	✓				✓				
Requires social science knowledge			✓				✓		
Online training available for modelling tools		✓		✓	✓	N/A	✓	N/A	✓
User support available	✓	✓		✓	✓	✓			✓

3. Practical considerations

Table 4

DECISION TREES

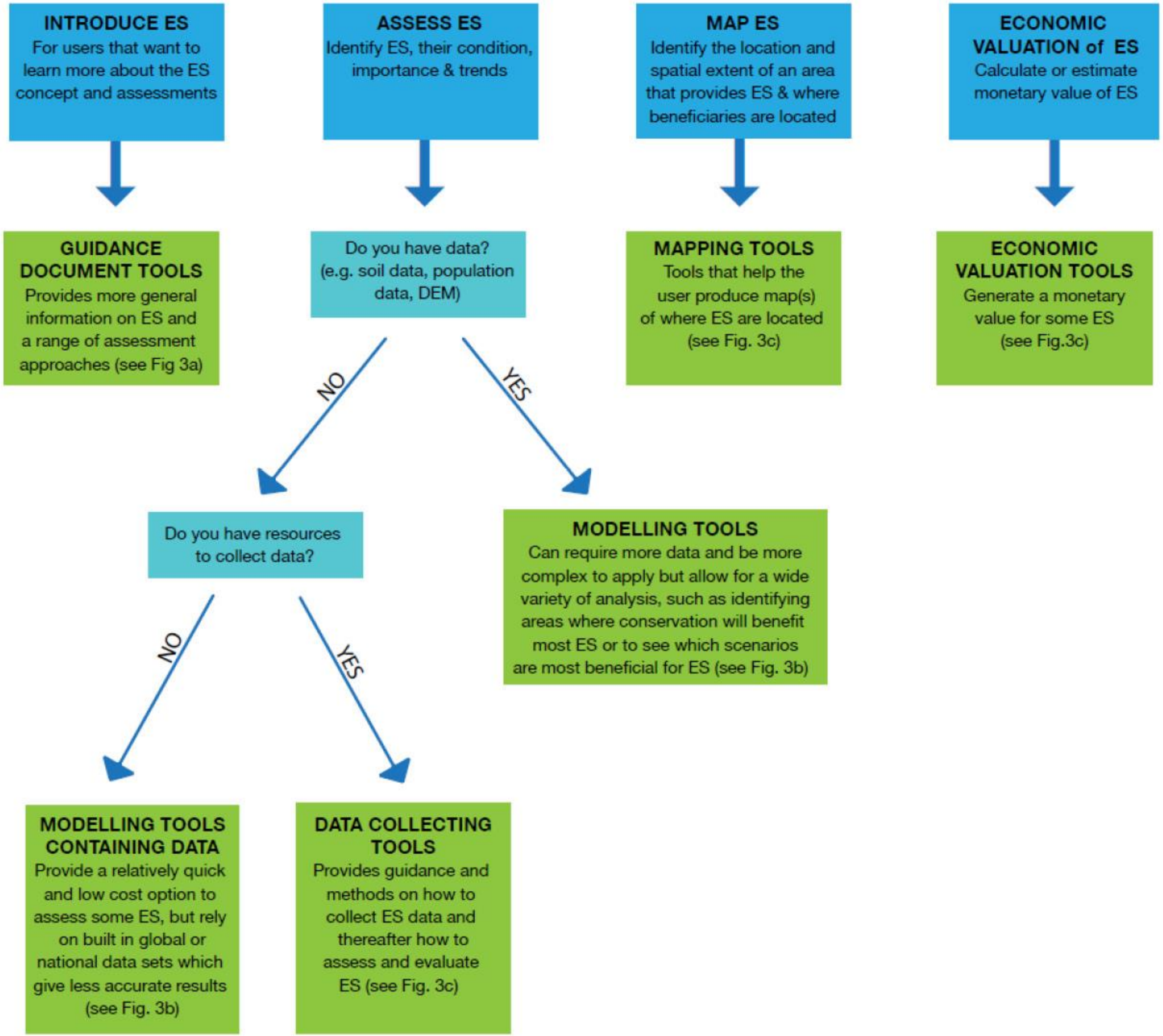


Figure 3

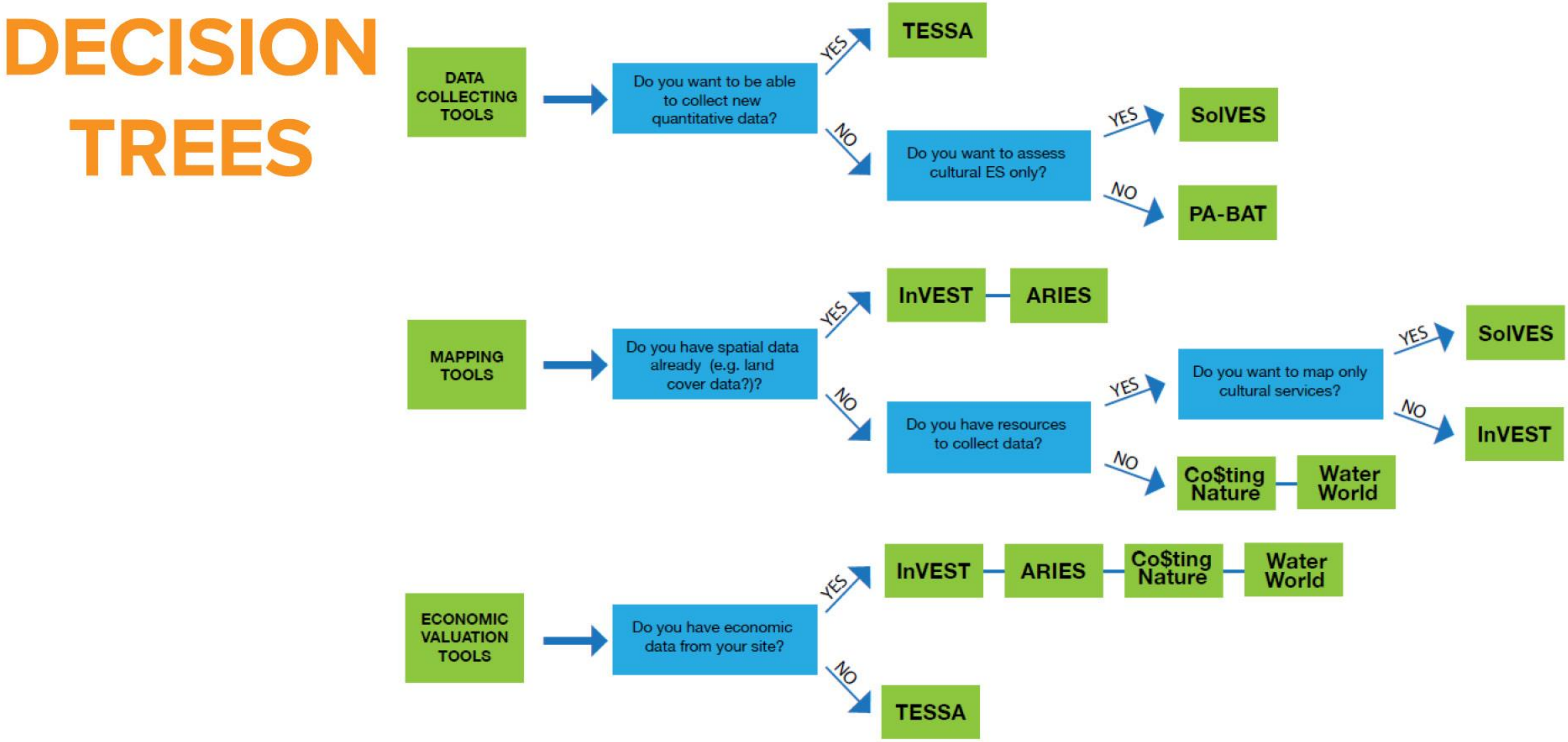

DECISION TREES
DATA COLLECTING TOOLS
Do you want to be able to collect new quantitative data?
YES
TESSA
NO
Do you want to assess cultural ES only?
YES
SolVES
NO
PA-BAT
MAPPING TOOLS
Do you have spatial data already (e.g. land cover data?)?
YES
InVEST
ARIES
NO
Do you have resources to collect data?
YES
Do you want to map only cultural services?
YES
SolVES
NO
InVEST
NO
Co$ting Nature
Water World
ECONOMIC VALUATION TOOLS
Do you have economic data from your site?
YES
InVEST
ARIES
Co$ting Nature
Water World
NO
TESSA

Figure 3

DECISION TREES

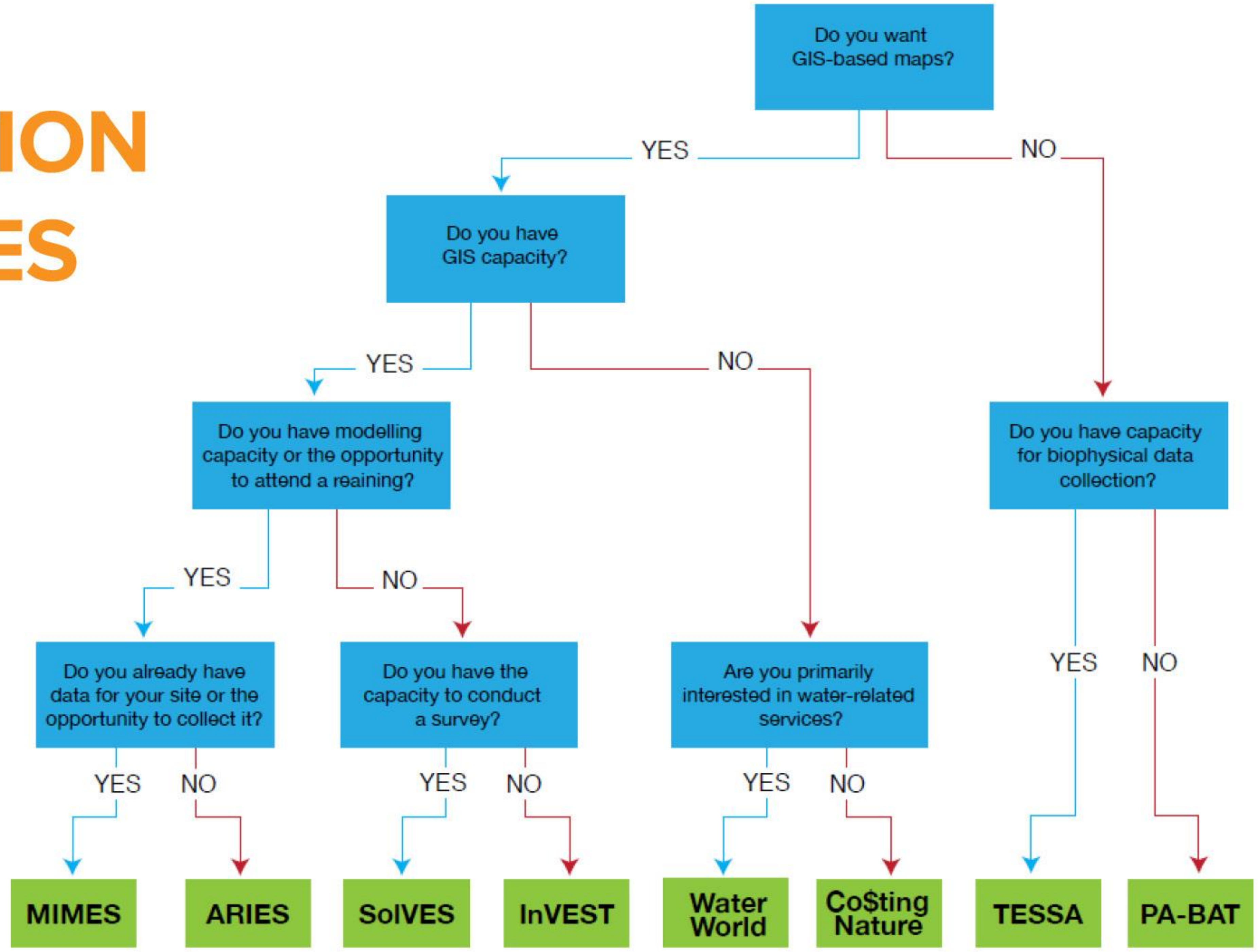


Figure 4

WHICH ECOSYSTEM SERVICES DO YOU WANT TO ASSESS?

Ecosystem Service	ARIES*	C$N	InVEST	PA-BAT	SolVES	TESSA	WW
Provisioning							
Fisheries / Subsistence fisheries (wild)		✓	✓	✓		✓	
Freshwater aquaculture		✓				✓	
Fuelwood		✓		✓		✓	
Genetic material				✓			
Harvested wild goods / Hunting / Non-wood forest products (e.g. honey, mushrooms, berries)		✓		✓		✓	
Livestock grazing		✓		✓		✓	
Marine fish aquaculture	✓		✓	✓			
Material extraction (e.g. coral, shells, resin, rubber, grass, rattan)				✓		✓	
Medicinal resources				✓		✓	
Production / Cultivated goods / Traditional agriculture				✓		✓	
Timber		✓		✓		✓	
Water - Water provision / Water supply / Water quantity / Water yield	✓	✓	✓	✓		✓	✓
Regulating							
Carbon (sequestration)		✓	✓			✓	
Carbon (storage) (terrestrial)	✓	✓	✓	✓		✓	
Coastal blue carbon	✓		✓				
Coastal protection / Coastal flood regulation / Coastal vulnerability		✓	✓	✓		✓	
Erosion		✓		✓		✓	✓
Flood protection / Flood regulation / Flood prevention	✓	✓		✓		✓	✓
Greenhouse gas flux						✓	
Landslide risk / Soil stabilisation / Avalanche protection	✓	✓		✓			
Pest & disease regulation		✓		✓			
Pollination / Crop pollination	✓	✓	✓	✓		✓	
Sediment retention / Sediment regulation / Sediment delivery / Sediment provision	✓		✓	✓			✓
Seasonal water yield - regulation of timing		✓	✓			✓	✓
Water purification / Water quality		✓	✓	✓		✓	✓

Table 5

WHICH ECOSYSTEM SERVICES DO YOU WANT TO ASSESS?

Ecosystem Service	ARIES*	C$N	InVEST	PA-BAT	SolVES	TESSA	WW
Cultural							
Cultural and historical values / Cultural heritage / Inspiration, creative or artistic / Social relations/community benefits		✓		✓	✓	✓	
Health, mental & physical				✓		✓	
Peace & stability				✓			
Research / Knowledge				✓	✓	✓	
Education				✓		✓	
Recreation / Nature tourism / Leisure	✓	✓	✓	✓	✓	✓	
Spiritual values / Sacred natural sites				✓		✓	
Sense of place / Identity						✓	
Scenic quality / Aesthetic viewsheds	✓		✓	✓	✓	✓	
Wilderness and iconic values [as a cultural value]				✓	✓	✓	
Other benefits that can be modelled/assessed							
Employment				✓			
Existence / Bequest value						✓	
Habitat quality / Nature conservation / Biodiversity		✓	✓	✓			
Habitat risk assessment		✓	✓				

Table 5

SUMMARY TABLES

Table 6

Criterion	ARIES	Co$ting Nature	EST	InVEST	MIMES	PA-BAT	SolVES	TESSA	WaterWorld
Cost & open/closed source	Free, open-source	Free (policy analyst or scientist version) or paid license (advanced user or commercial versions), closed-source	Free, open-source	Free, open-source	Free, open-source; requires purchase of SIMILE software (closed-source)	Free, open-source	Free, requires purchase of ArcGIS software (closed-source)	Free, open-source	Free (policy analyst or scientist version) or paid license (advanced user or commercial versions), closed-source
Availability	Available	Available	Available	Available	Available	Available	Available	Available	Available
Time requirements	Low for global models; High for new case studies	Low	Low to high	Moderate to high	High for new case studies	Low to moderate	Low to high	Low to high	Low
Data input demand	Low to high	Low	Low to high	Moderate to high	Moderate to high	Low	Low to moderate	Moderate to high	Low
Skill requirements	Low to high	Low	Low to high	Moderate to High	High	Low	Moderate	Low	Low
Scale of analysis	Local to global	Local to global	Local to global	Local to global	Local to regional	Local	Local to regional	Local	Local to global
Quantitative / Qualitative	Quantitative or Qualitative	Quantitative (relative values)	Quantitative or Qualitative	Quantitative or Qualitative	Quantitative	Qualitative	Quantitative	Quantitative or Qualitative	Quantitative (absolute physical magnitudes)
Monetary / Nonmonetary	Monetary or nonmonetary	Monetary or nonmonetary	Monetary or nonmonetary	Monetary or nonmonetary	Monetary or nonmonetary	Nonmonetary	Nonmonetary	Monetary or nonmonetary	Nonmonetary
Spatially explicit	Yes	Yes	Either	Yes	Yes	No	Yes	No	Yes
Technical requirements	Computer and internet access	Computer and internet access	None	Computer, GIS software	Computer access, Similie software, GIS software	None	Computer, ArcGIS	Field equipment (optional)	Computer and internet access
User support	Moderate	Moderate	Low	High	Moderate	Moderate	Moderate	Low	Moderate
Level of development & documentation	Case studies & global models developed and documented	Partially documented	Fully developed and documented	Fully developed and documented	Case studies developed and documented	Fully developed and documented	Fully developed and documented	Fully developed and documented	Partially documented

SUMMARY TABLES

Criterion	ARIES	Co$ting Nature	EST	InVEST	MIMES	PA-BAT	SolVES	TESSA	WaterWorld
Range of time for full application in a new site (scoping, data collection, analysis follow-up)	Days to weeks for pre-existing models; months to a year for a new case study	Minutes to hours for application of the model with all provided data	Hours to days for scoping process; highly variable for a complete assessment depending on the methods/ tools selected, resources / capacity of assessment team, and extent/quality of results expected	1-3 months for smaller projects, less if data exist and scenarios identified up-front; 6 months to 2 years for larger projects with multiple ES, depending on level of stakeholder involvement	3 months to learn model functioning, 1-3 months for smaller projects, 6 months to 2 years for larger projects	1 day workshop, days to weeks for preparation, subsequent analysis of workshop results, follow-up	Months to a year for survey design and gathering survey data; minutes to run the model once survey data are available	20-60 person days for prepa-ration, primary data collection (biophysical and socioeconomic), and analysis	Minutes to hours for application of the model with all provided data
General summary / insights	Spatially explicit ecosystem service trade-off, flow and uncertainty maps; currently time consuming for new applications, unless using global models	Rapid analysis of indexed, bundled services based on global data, along with conservation priority maps	Detailed step-by-step guide with built-in tools to complete ES assessment including analysis of biophysical, sociocultural, and economic values; compendium of additional tools, methods, and data sources; and guide to using results in multiple policy/decision contexts	Spatially explicit ecosystem service trade-off maps; currently relatively time consuming to parameterise	Dynamic modelling and valuation using input–output analysis; ecosystem trade-off and decision making, highly time consuming to develop	Qualitative paper-based forms for protected area managers and stakeholders to assess benefits provided by protected areas	Provides maps of social values for ecosystem services; time consuming for new studies but lower-cost for value transfer	A collection of site-based comparative assessment methods targeted at practitioners without specialised skills	Rapid analysis of detailed biophysical assessment based on global data, along with conservation priority maps

Table 6

ANNEX II: TOOL DESCRIPTIONS & CASE STUDIES

1. Short description of the tool
2. User requirements (software, data, expertise)
3. Which ecosystem services can be modelled with the tool?
4. Can it be applied in terrestrial, freshwater, and coastal/marine contexts?
5. Strengths or unique features that set it apart from other tools
6. Limitations
7. Potential applications for conservation
8. Case studies
9. Approximate time (staff-days) and cost of a full application of the tool in a new context

Annex II. Description of tools and case studies

A short description of each tool including user requirements, strengths and limitations, potential applications for important sites, and case studies in which the tools have been applied at the site level are summarised below. We have focused here on tools that are available at no cost and can be applied in new contexts (i.e. they are not restricted to specific countries or case studies). For a more comprehensive set of tool descriptions, please see the ValuES Database (www.aboutvalues.net/) and the Ecosystem Services Toolkit (Value of Nature to Canadians Study Taskforce, 2017).

Artificial Intelligence for Ecosystem Services (ARIES)

Description

Artificial Intelligence for Ecosystem Services (ARIES; aries.integratedmodelling.org/) is an ES modelling platform (Villa et al., 2014). Theoretically, any ES can be modelled using ARIES, but currently (early 2018) the following ES models have been developed and tested: carbon storage, flood regulation, pollination, and cultural / recreational values. Models for several additional ES are under development: mangrove carbon storage, mariculture suitability, water provision, landslide risk, and sediment provision. Case studies have also been developed for carbon sequestration, coastal protection, cultural values, erosion, fisheries, biodiversity, crop production, scenic value, and sediment retention/delivery.

User requirements

Currently ARIES consists of specialised software (a graphical user interface (GUI) for collaborative modelling) and a series of linked web-based databases for uploading, storing and accessing data. Thus, ARIES currently requires specialised expertise or training, unless the user is running global models (available at the time of this review) on a web interface (planned for completion before fall 2018), in which case models are much more accessible to non-technical users. The data flow and parameterisation of global models is fully automated. However, applying non-global models in new contexts requires the user provide all the necessary input data (unless using global data that are already integrated into the modelling system) as well as specify all the model parameters and algorithms. By late 2018, a web-based application will be developed.

Strengths

ARIES can accommodate sophisticated modelling techniques including agent-based modelling in which the behaviour of individual actors, such as individuals or groups, is simulated, to assess effects on the system. ARIES can also accommodate dynamic modelling, in which model processes change over time, and machine learning, where model relationships are learned from data. ARIES also can account for uncertainty (Villa et al., 2014). Two unique contributions made by ARIES to the universe of ES assessment tools is a standardised lexicon or semantics, in which a given term such as "aboveground biomass carbon storage," is always defined and measured consistently, no matter which model or analysis it appears in. This enables ARIES to match data and models to the appropriate spatial and temporal context and scale, overcoming common challenges of unit and/or scale matching and contextualisation in ES modelling. A second contribution is the creation of a global database and model repository where users submit relevant datasets and models; over time, this will become an invaluable resource as data limitations are often the key factor hindering ES assessments. The collaborative, cloud-based, context-specific elements of ARIES distinguish it from other approaches. Specifically, collaborative modelling via web platforms such as BitBucket allows a community of modellers to contribute and re-use models. Finally, the automated production of reports describing the modelling methodology and results enables global models to be run and the outputs readily understood (Willcock et al., In press).

Limitations

ARIES currently requires specialised training. User documentation is available via an online collaborative forum (integratedmodelling.org/confluence/). Currently for all new case studies, ARIES requires a user to have specialised expertise, provide all the necessary data, and specify all the model parameters and algorithms (unless utilising global data and models). Training is available (springuniversity.bc3research.org/). As a result, model customisation is time and data-intensive, making it impractical for rapid ES assessments, and so use of global data and models within ARIES is recommended for these occurrences.

Potential applications for KBAs, WHS and PAs

For nontechnical users, ARIES' global models provide a uniform package of models that can be run anywhere using global datasets, but for which local data can be easily substituted (particularly when the accessibility of these models is improved by the release of the web browser interface). ARIES also provides a sophisticated modelling approach for users who wish to gain specialised training, provide their own data, and specify the model parameters themselves. Because it can accommodate agent-based modelling, dynamic modelling, machine learning, and uncertainty, ARIES is an advanced solution for addressing the complexity of socio-ecological processes. Models developed within ARIES could provide detailed information about the interacting effects of multiple user groups, for example, or variation in ES flows over time.

Summary

ARIES is one of the more sophisticated tools included in this review, and as such has the potential to provide information about ES that reflects the complex, dynamic, interactive flows of benefits from nature to people. Due to the requirements for specialised expertise, data and time to apply ARIES in new contexts, however, it also represents one of the most time consuming and challenging tools to apply, except when the user wants to use global models that have already been developed, tested, and served through a web-based interface. In the future (by late 2018) the online user interface will make it easier for non-experts to use.

ARIES Case Study:

Evaluating biophysical and cultural ecosystem service hotspots using ARIES and SolVES to inform national forest planning in the United States

Context: The USDA Forest Service has been a leader among U.S. land management agencies in advancing the use of ES concepts and tools for forest planning, in part as an outgrowth of their 2012 Planning Rule. Given the inherently spatial nature of forest planning, two ES tools were jointly applied to map different aspects of forest ecosystem services, and then their results were combined to buid more informative maps for managers. First, the ARIES modelling platform was used to model four biophysically-based ES across six national forests in the Rocky Mountains of Colorado and Wyoming. Second, survey data on public values (largely corresponding to cultural ES) for the same national forests with the SolVES tool were used to model these values spatially. By estimating biophysical and cultural ES 'hotspots' (high ES value areas) and 'coldspots' (low ES value areas) and overlaying the two, a matrix of biophysical/cultural hot-warm-coldspots across a large extent of public lands in the Rocky Mountains region of the western U.S. was produced, with distinct management implications. For example, a biophysical-cultural ES hotspot analysis can identify regions where traditional uses are strongly supported by managers or may require further evaluation for conflicts, areas suitable for development or resource extraction, and areas where public outreach might be needed to build support for management (Figures A1 and A2).

Motivation/question being addressed: This analysis builds on an earlier analysis from Colorado's Pike-San Isabel National Forest to evaluate the use of alternative hotspot methods across a wider region of national forests in the U.S. Rocky Mountains. Six different hotspot methods (quantile, area-based, and statistical) were tested to determine their sensitivity for identifying ES hot/coldspots. The presence of ES hot/coldspots in wilderness vs. non-wilderness areas of the National Forests across a gradient from urban proximate (forests near the Colorado Front Range urban corridor) to remote (northwest Wyoming) were also evaluated.

Location/scale: The analysis was conducted for six U.S. National Forests in the states of Colorado and Wyoming (an area totalling almost 57,000 km²) at a 450 m resolution.

Time and resources: The project entailed synthesis of existing ARIES and SolVES models for the Rocky Mountains. ARIES models were developed, tested and refined over a total period of about 9 months. SolVES data were derived from three separate surveys of national forests, conducted over an 8-year period. The time to develop, pilot test, and administer surveys by mail was roughly 9-12 months for each survey. Digitising survey data, preparing environmental data, and running SolVES took an additional 2-4 weeks.

Linked to other tools: The ARIES and SolVES tools were used jointly to show the complementarity of biophysical models and public participatory GIS approaches for more comprehensively assessing ES and potential public awareness/support for relevant management actions.

Stakeholders/collaborators/partners: This project was led by the U.S. Geological Survey. The USDA Forest Service was consulted during the development of the project and dissemination of results. SolVES surveys were developed and administered in collaboration with social science researchers at Colorado State University.

Services assessed: Four biophysical ES were modelled using ARIES: carbon sequestration and storage, scenic viewsheds, sediment retention, and water yield. Eleven social value types/cultural ES were mapped using SolVES: aesthetic, cultural, economic, future, historic, intrinsic, learning, recreational, spiritual, subsistence, and therapeutic value.

Beneficiaries: Scenic viewsheds were calculated for residents living within view of the six national forests and from recreation sites located within the national forests. Given the forests' location at the headwaters of a number of major rivers (Arkansas, Colorado, Green, Missouri, Platte, and Snake Rivers) with significant downstream beneficiaries, it was assumed that hydrologic ES (sediment regulation and water yield) were used uniformly by downstream water users. Beneficiaries of carbon sequestration and storage were assumed to be global. Cutural ES data were collected from surveys of residents in counties surrounding the national forests.

Key results: The six hot/coldspot delineation methods identify distinctly different numbers and edge-to-area ratios for hot/coldspots, with important implications for management when hot/coldspot methods are used in decision making. For large national forests, methods of intermediate conservatism that produced clustered hot/coldspots (i.e. statistical methods) may be most informative for planning. Hotspots were more common and coldspots less so in wilderness areas of four national forests closest to the Colorado Front Range urban corridor, while the opposite pattern was observed for two more remote national forests in northwest Wyoming. These trends are likely due to differing demographics and values for wilderness areas of residents living near these forests. They align well with past findings about public attitudes toward wilderness, to which these results add a spatial dimension. This work shows how information from cultural ES assessments using public participatory GIS techniques (mapped using the SolVES

ANNEX III: MORE TOOLS

	Cost and availability for application to new sites				Scale and environmental context			Time, data and resources requirements					
Criterion	**Cost**	**Availability**	**Open source (for software)**	**Generalizability / Applicability in new contexts**	**Capacity for independent application**	**Single/ multiple site**	**Scale of analysis**	**Applicable to terrestrial, freshwater, marine**	**Time requirements**	**Data input demand**	**Technical requirements**	**Skill requirements**	**Interface**	**Level of stakeholder engagement required**
WHBET	Free; requires MS Excel software	Available	Requires use of MS Excel	Low; currently developed for the US only	Yes, within the U.S.	Single or multiple	Local to regional	Terrestrial, freshwater	Low	Low	Computer and internet access, MS Excel	Low	Excel spreadsheets (.xls)	Low
An introductory guide to valuing ES	Free	Available	N/A	High	Yes	Single or multiple	Local to global	All	Low	Low	None	Low	Pdf guidance document	N/A
EcoSERVE	Free	Available	Requires use of ArcGIS	UK specific	Yes	Single	Local	Terrestrial and freshwater	High	Medium	ArcGIS with the Spatial Analyst Extension	High	Requires use of ArcGIS	Low
Ecosystem Services Assessment: how to do one in practice	Free	Available	N/A	High	Yes	Single or multiple	Local to global	All	Low	Low	None	Low	Pdf guidance document	N/A
Ecosystem Services Assessment Support Tool	Free	Available	N/A	High	Yes	Single or multiple	All	All	Low	None	Computer, internet access	Low	Online guidance	None
Ecosystem services identification and inventory tool	Free for version one	Available	Closed source	High	Yes	Single	Local	All (but not tested in marine environments)	Medium	High (field data collection)	Computer or iPad for the app	Low	Web-based or an app	Low
Ecosystem Services Partnership Visualization Tool (ESP-VT)	Free	Yes	N/A	N/A	Yes	N/A	Local to national	All	Low	Low	Computer, internet access	Low	Website	None
Ecosystem services Valuation Toolkit (EVT)	Not available currently	At present, EVT is an internal tool for access by Earth Economics team members only	N/A	Low	No	N/A	All	All	Low	None	Computer, internet access	Low	Database	None
EnviroAtlas	Free	Available	N/A	USA only	Yes, within the USA	Sinlge or multiple	Local to national	All	Low	None (included in the tool)	Computer and internet access	Medium	Web application	Low

IUCN

Tools for measuring, modelling, and valuing ecosystem services

Guidance for Key Biodiversity Areas, natural World Heritage sites, and protected areas

Rachel A. Neugarten, Penny F. Langhammer, Elena Osipova, Kenneth J. Bagstad, Nirmal Bhagabati, Stuart H. M. Butchart, Nigel Dudley, Vittoria Elliott, Leah R. Gerber, Claudia Gutierrez Arrellano, Kasandra-Zoica Ivanić, Marianne Kettunen, Lisa Mandle, Jennifer C. Merriman, Mark Mulligan, Kelvin S.-H. Peh, Ciara Raudsepp-Hearne, Darius J. Semmens, Sue Stolton and Simon Willcock

Craig Groves, Series Editor

https://portals.iucn.org/library/node/47778

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Q & A
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ARIES framework

Smart technology: specifically developed for mapping and quantifying of ecosystem services, requires minimal training

Utilizes existing ecological-process models: those commonly used or previously published

Builds *ad hoc* probabilistic models: with an expert input, accounts for uncertainty, handles missing data

Machine learning: capable of deriving relationships from the data

Artificial intelligence: used for model selection

Capable to model service flow: agent-based approach accounts for spatial and temporal dynamics of service flows

ARIES Explorer

https://www.youtube.com/watch?v=vsWGkMBpI9Y

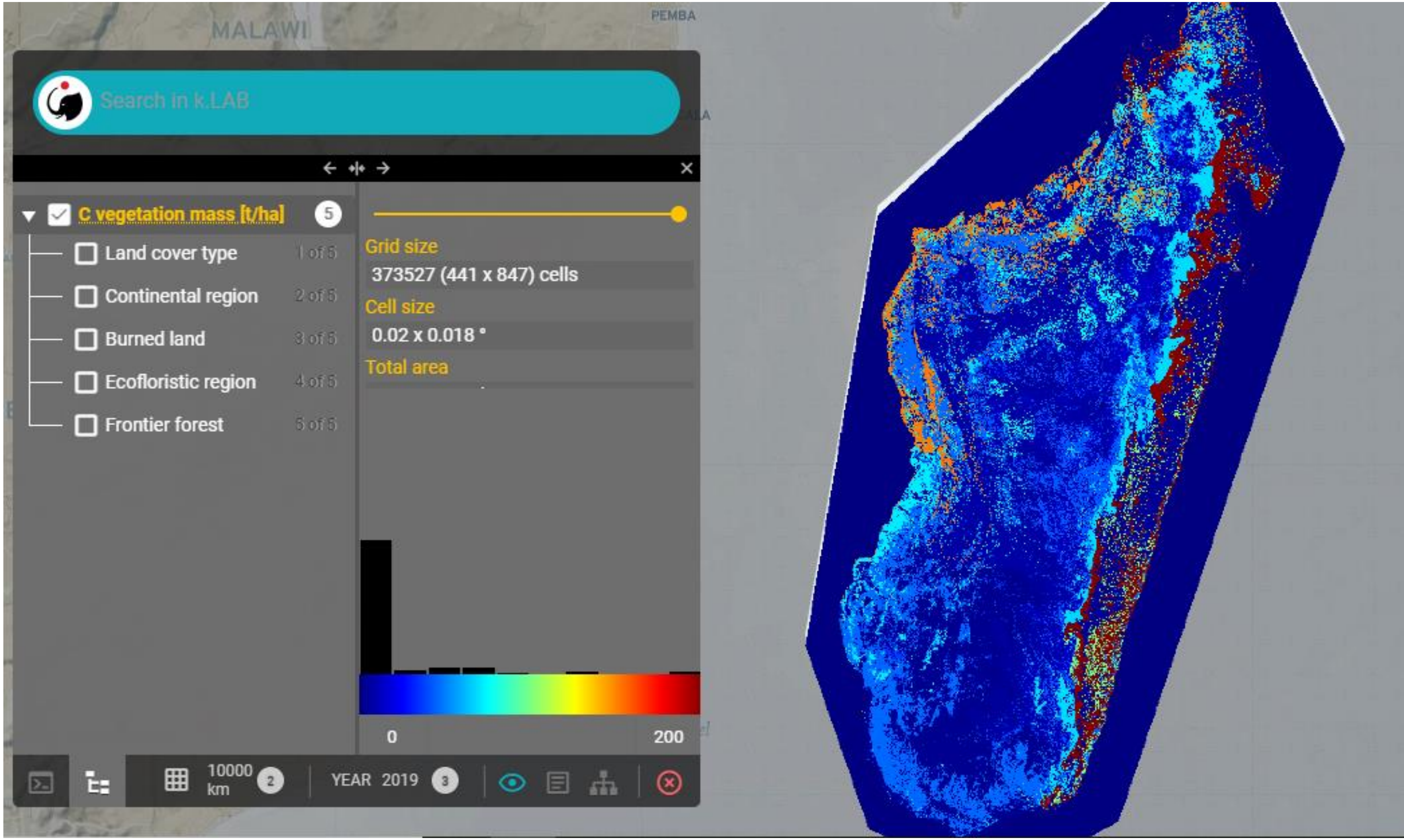
- displaying spatial data (0-7 mins)
- mapping ecosystem services (7-15 mins)
- spatial scenarios analysis (15-17 mins)
- importing your own data and models (17-20 mins)

Example of using the ARIES explorer in Madagascar

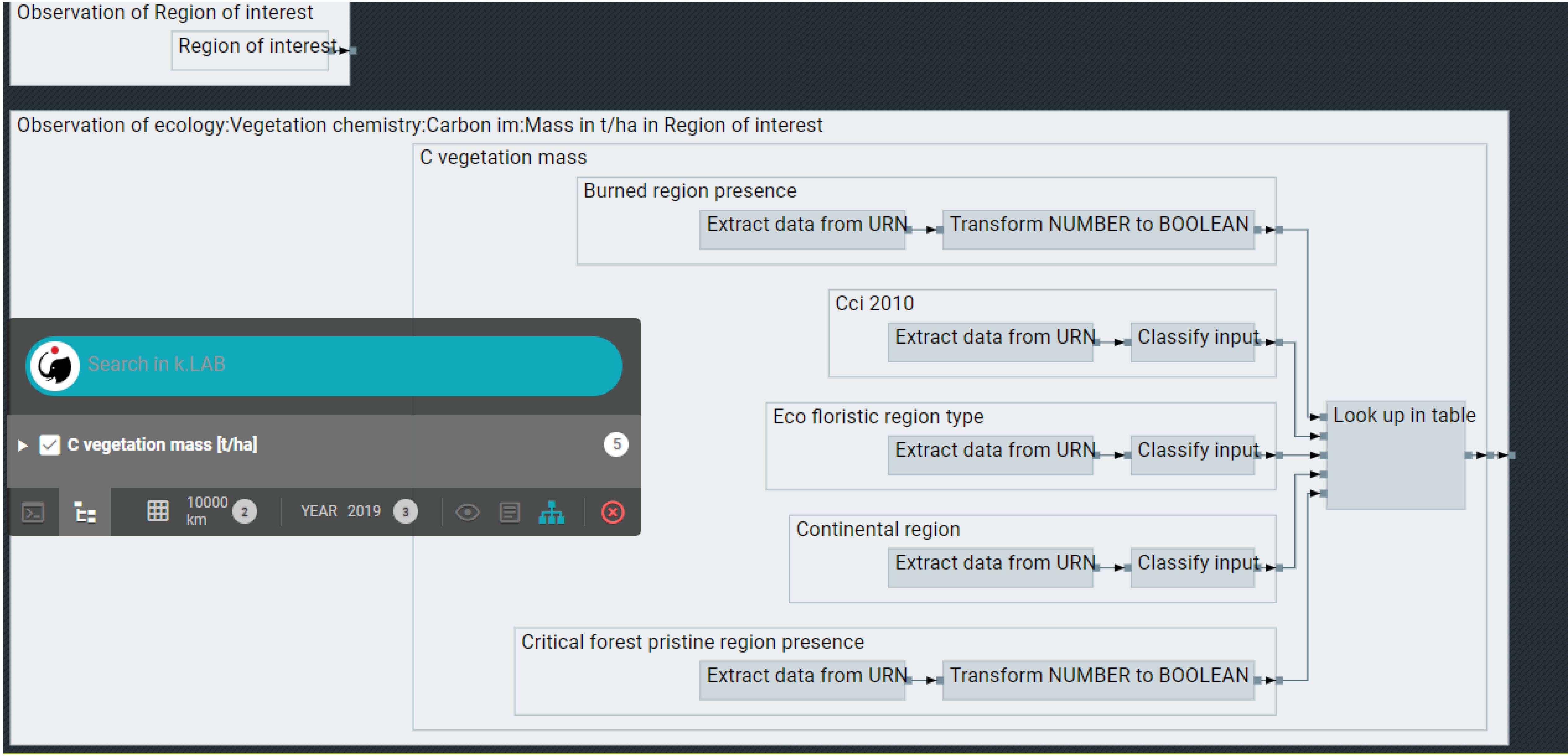
prepared by Rachel Neugarten

January 2019

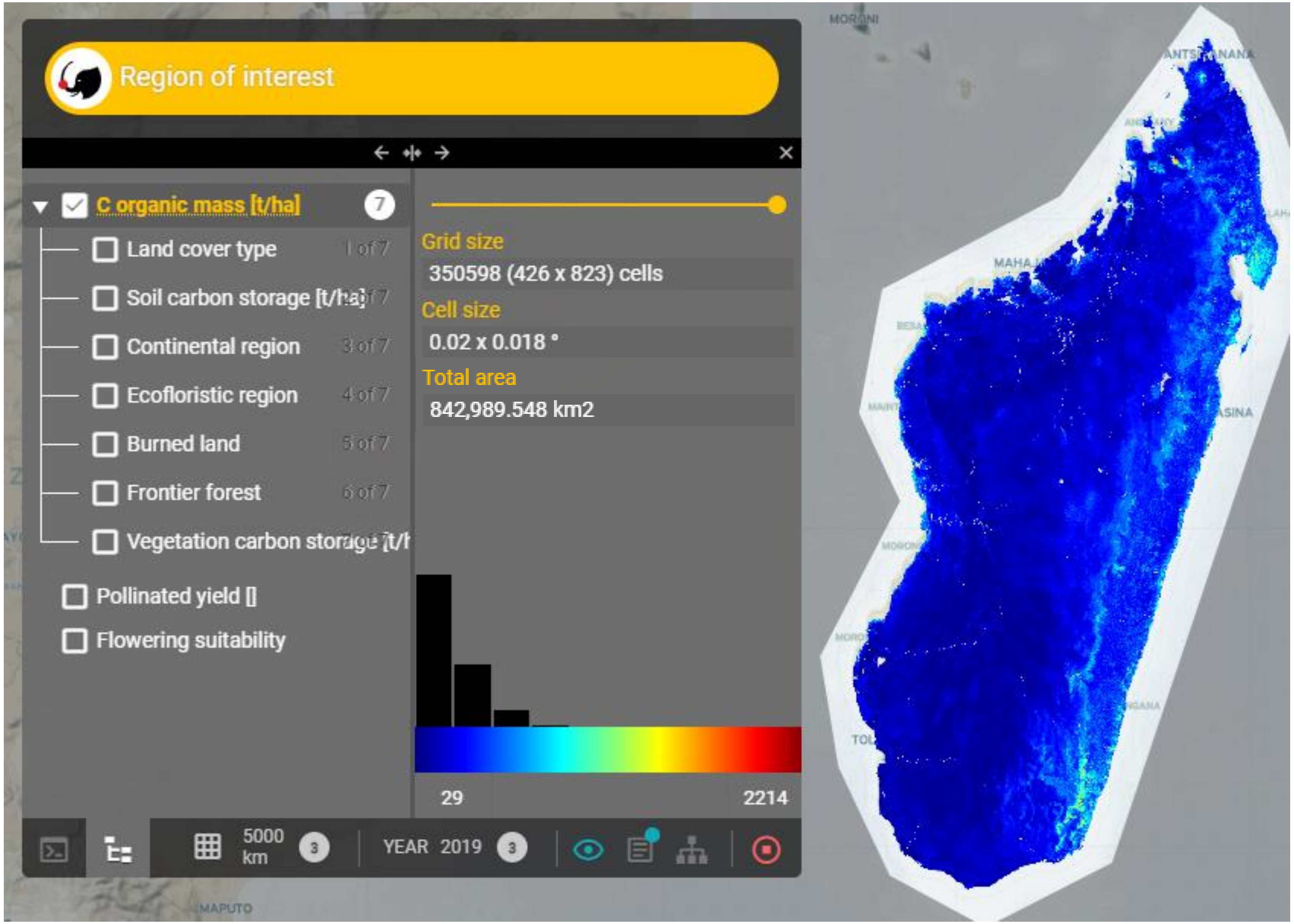
Carbon vegetation mass (t/ha)
10,000 km (?) resolution model run time: 4 min



Data flow

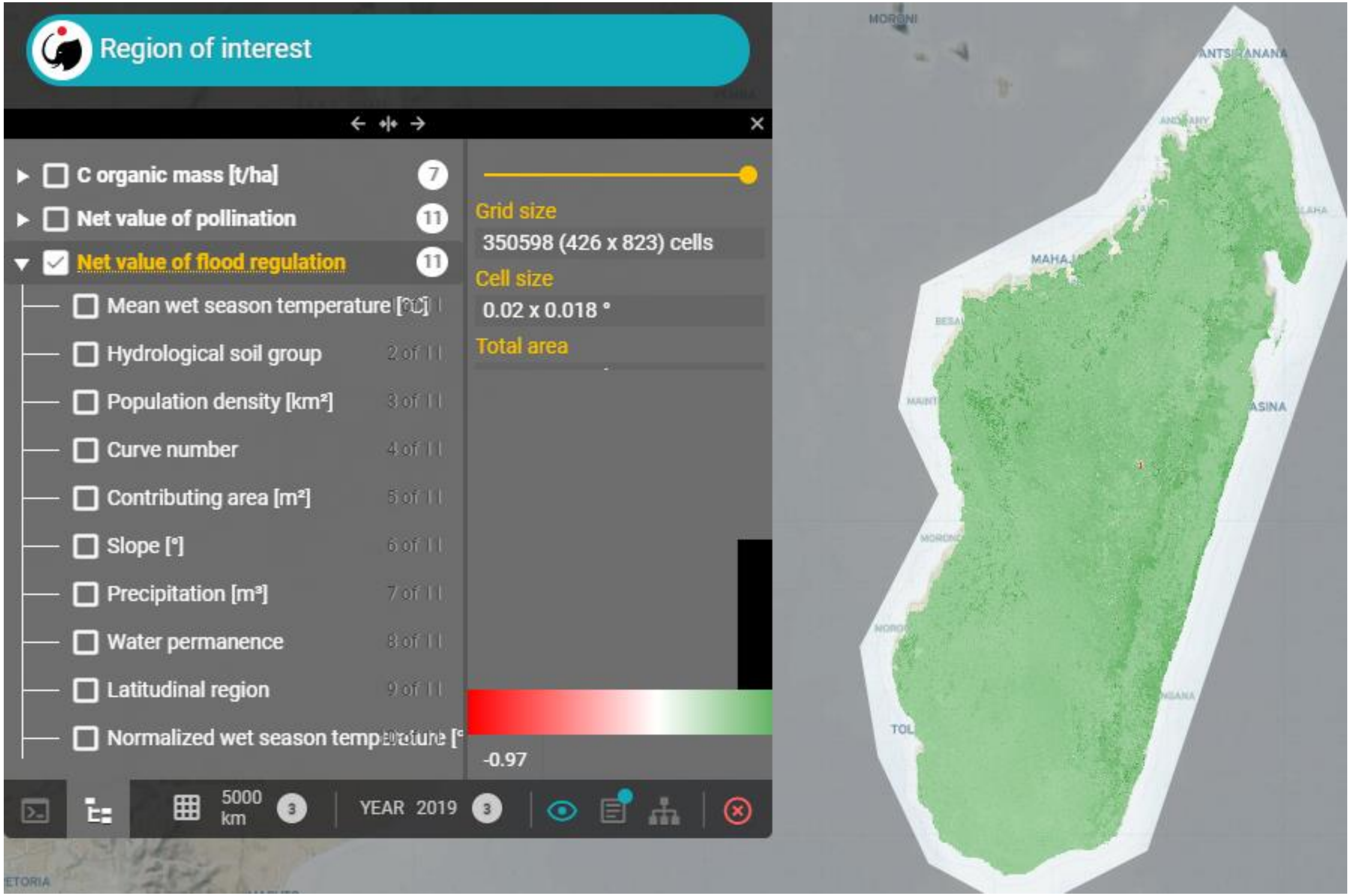

Observation of Region of interest
Region of interest
Observation of ecology:Vegetation chemistry:Carbon im:Mass in t/ha in Region of interest
C vegetation mass
Burned region presence
Extract data from URN
Transform NUMBER to BOOLEAN
Cci 2010
Extract data from URN
Classify input
Eco floristic region type
Extract data from URN
Classify input
Continental region
Extract data from URN
Classify input
Critical forest pristine region presence
Extract data from URN
Transform NUMBER to BOOLEAN
Look up in table
Search in k.LAB
C vegetation mass [t/ha]
5
10000 km
2
YEAR 2019
3

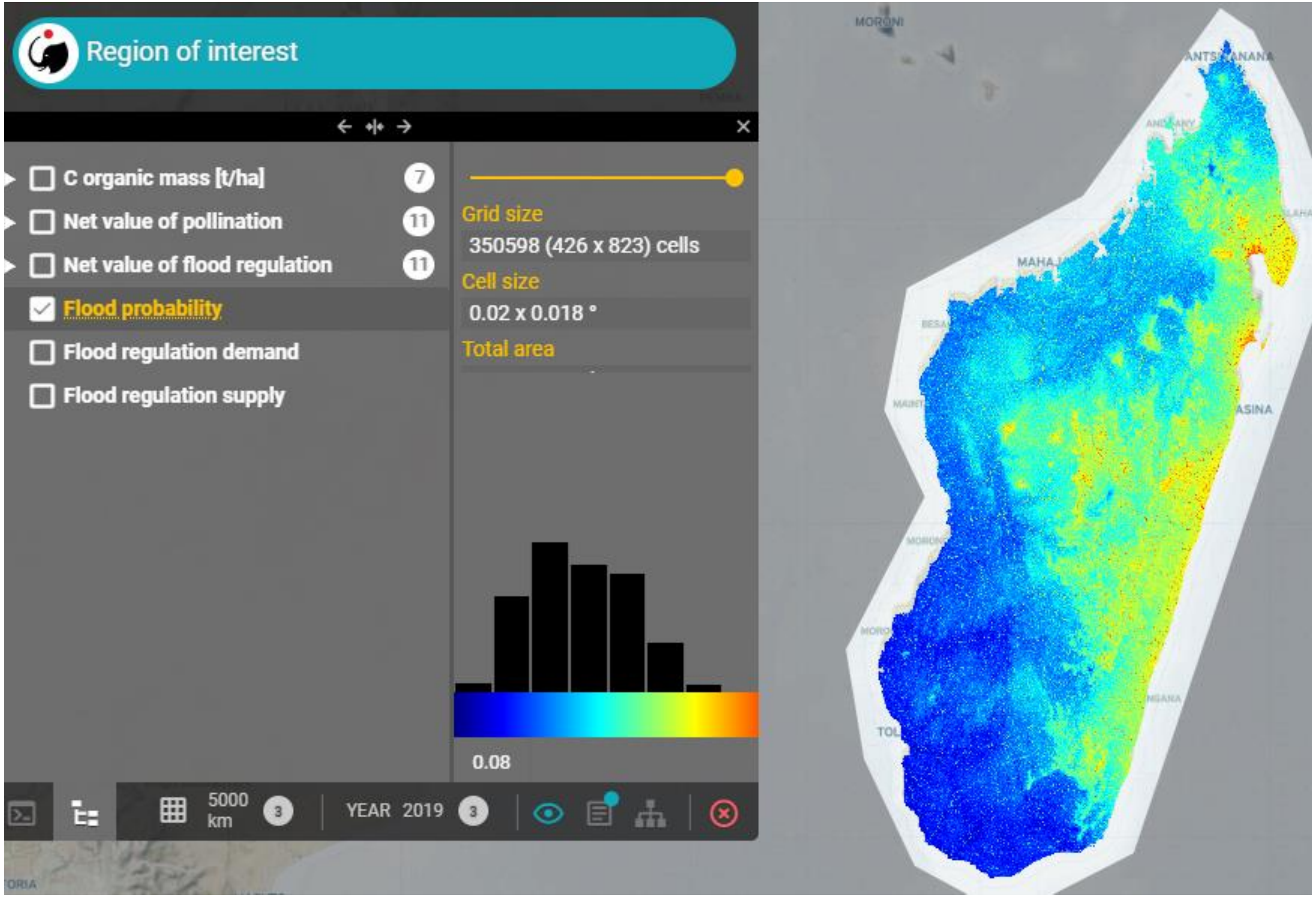
Carbon organic mass (soil?); 5,000 km2, run time <8 min



Net value of pollination (5,000 km2, run time 15 min)

Net value flood regulation (5,000 km2, run time 10 min)




Region of interest
C organic mass [t/ha]
7
Net value of pollination
11
Net value of flood regulation
11
Flood probability
Flood regulation demand
Flood regulation supply
Grid size
350598 (426 x 823) cells
Cell size
0.02 x 0.018 °
Total area
0.08
5000
km
3
YEAR 2019
3
MORONI
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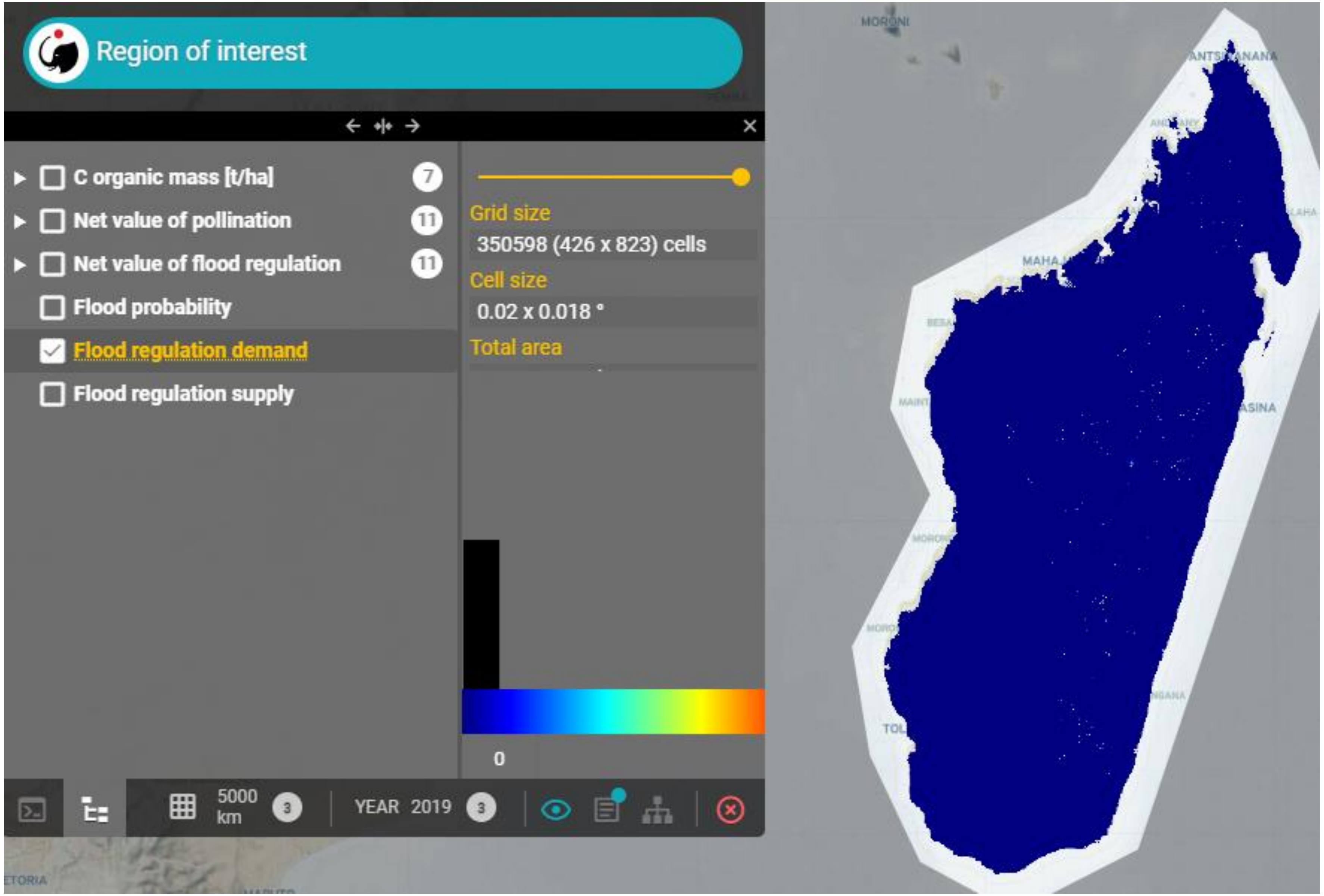
Region of interest
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Net value of pollination
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Net value of flood regulation
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Flood probability
Flood regulation demand
Flood regulation supply
Grid size
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Cell size
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Total area
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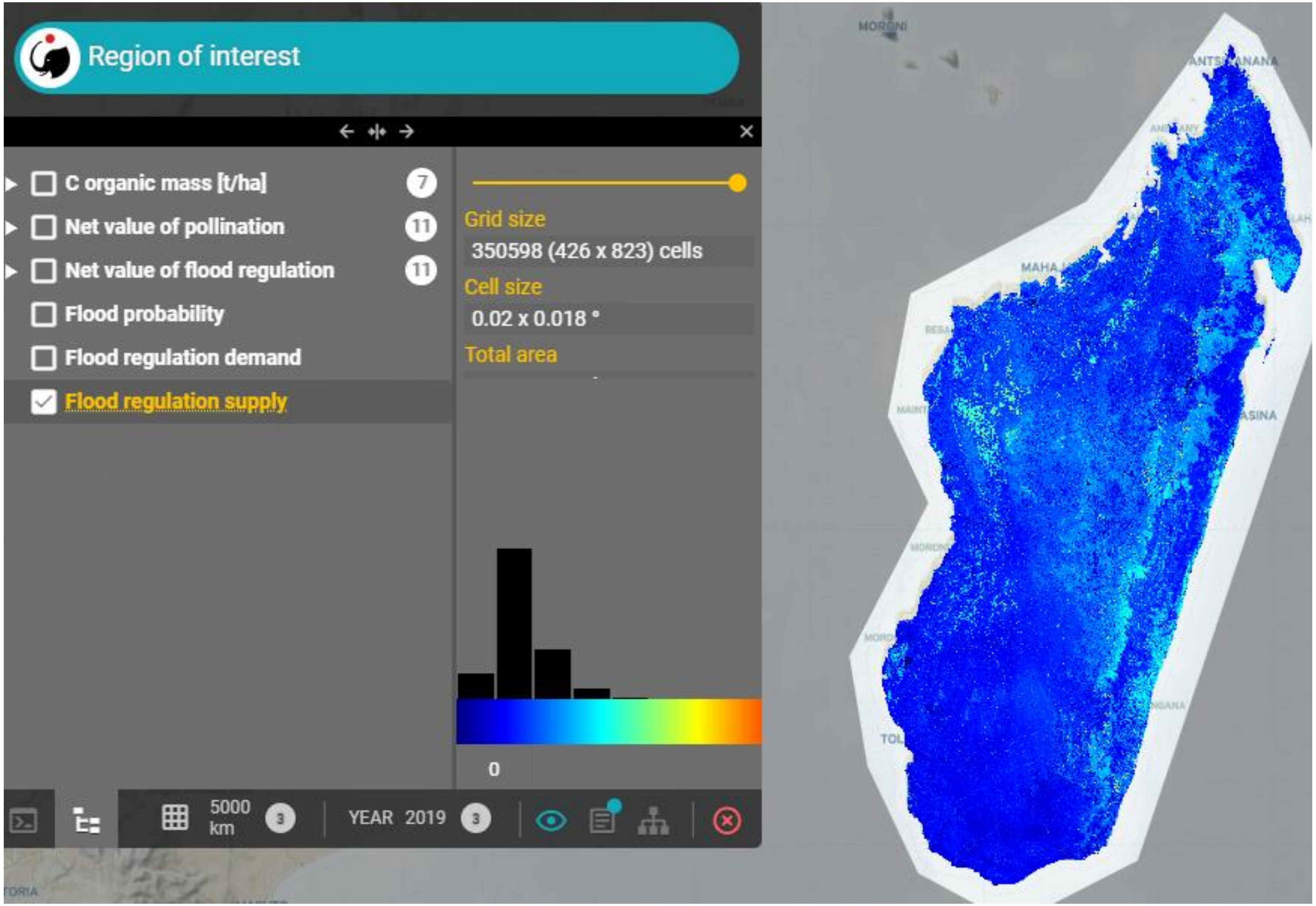
Region of interest
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Net value of pollination
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Net value of flood regulation
11
Flood probability
Flood regulation demand
Flood regulation supply
Grid size
350598 (426 x 823) cells
Cell size
0.02 x 0.018 °
Total area
0
5000
km
YEAR 2019
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ANTSIRANANA
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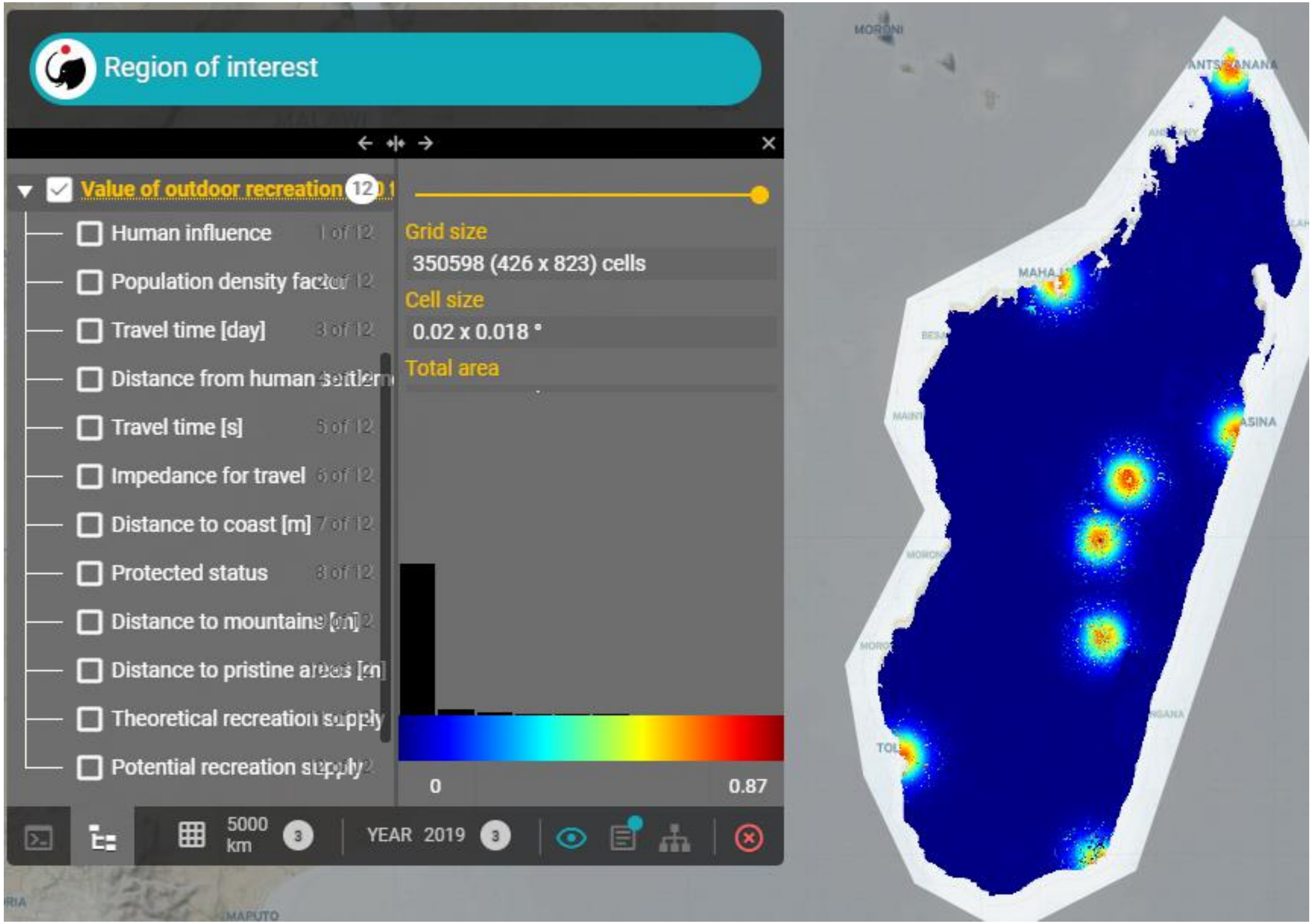
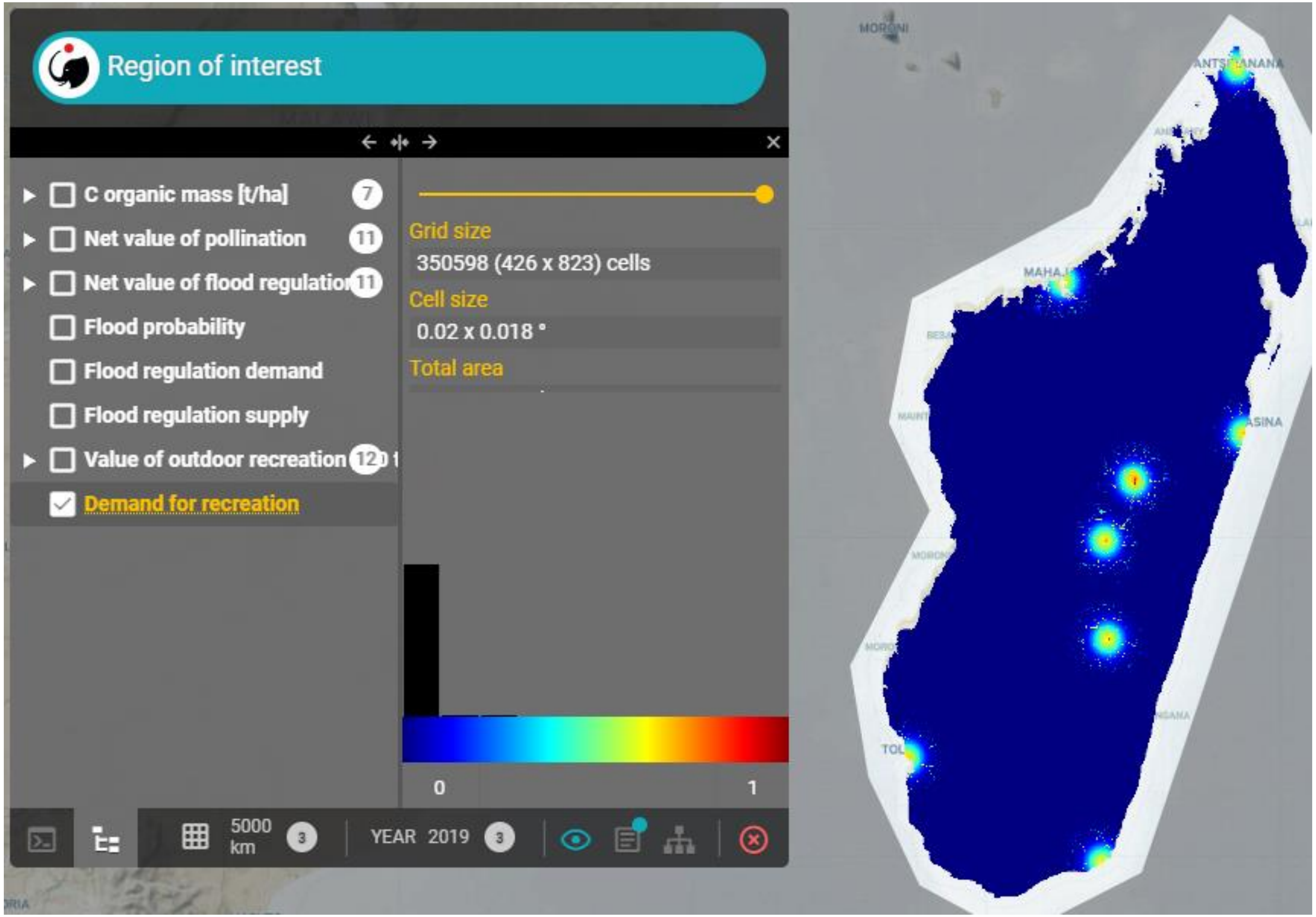
Value of outdoor recreation (5,000 km2, run time 10 min)





Region of interest
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Flood probability
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Flood regulation supply
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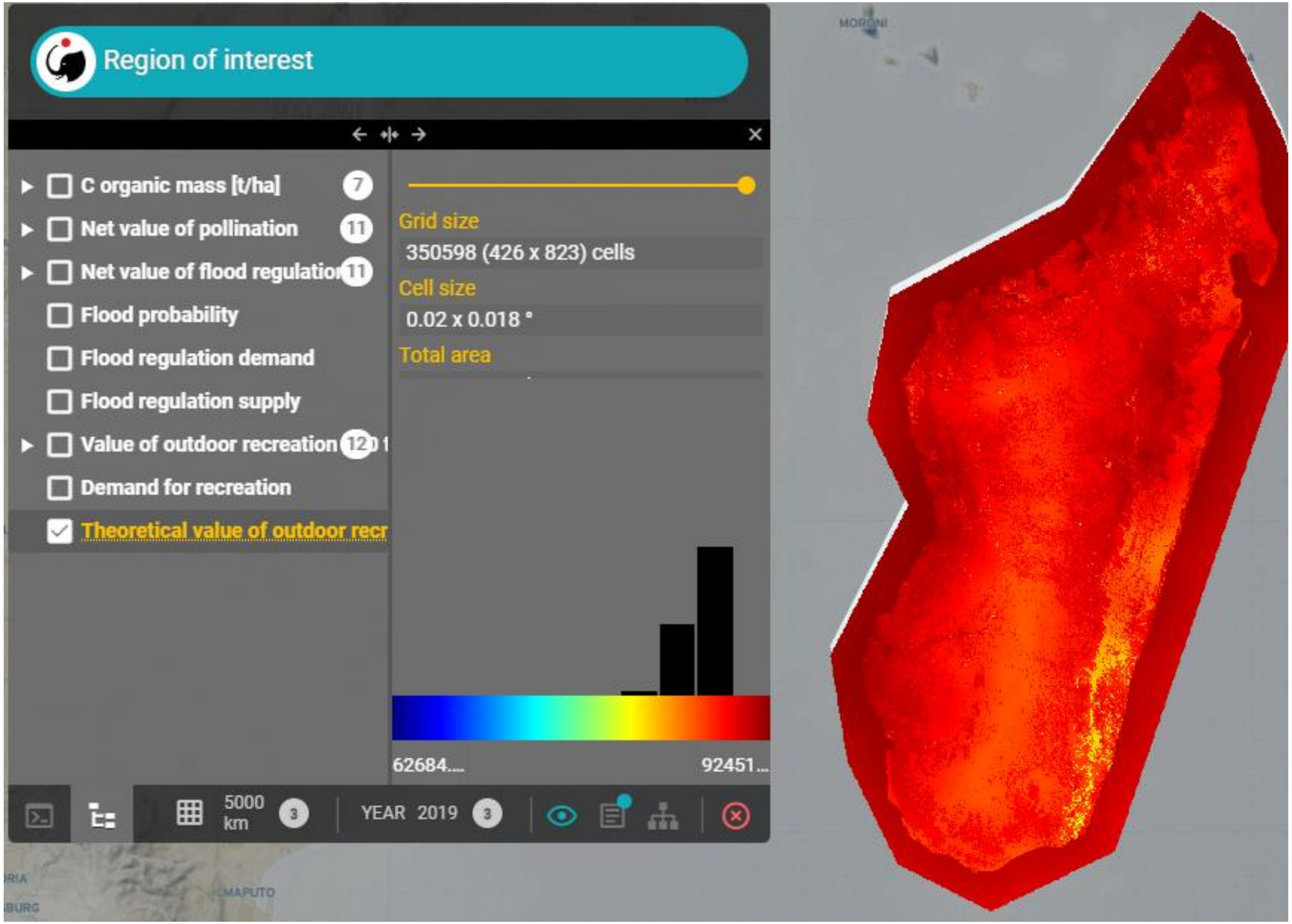

Region of interest
C organic mass [t/ha]
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Net value of pollination
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Net value of flood regulation
11
Flood probability
Flood regulation demand
Flood regulation supply
Value of outdoor recreation
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Demand for recreation
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Grid size
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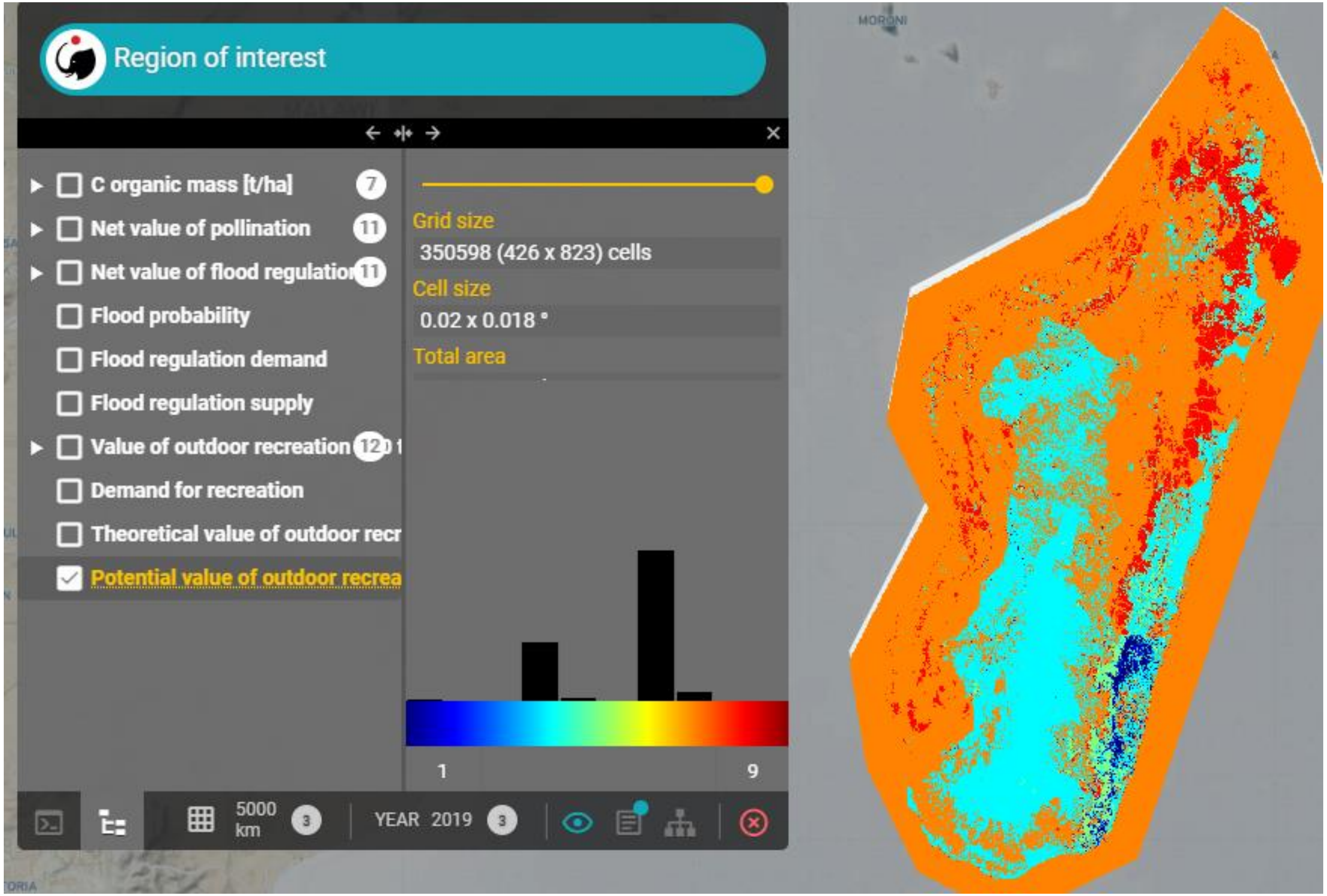

Region of interest
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Value of outdoor recreation
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Grid size
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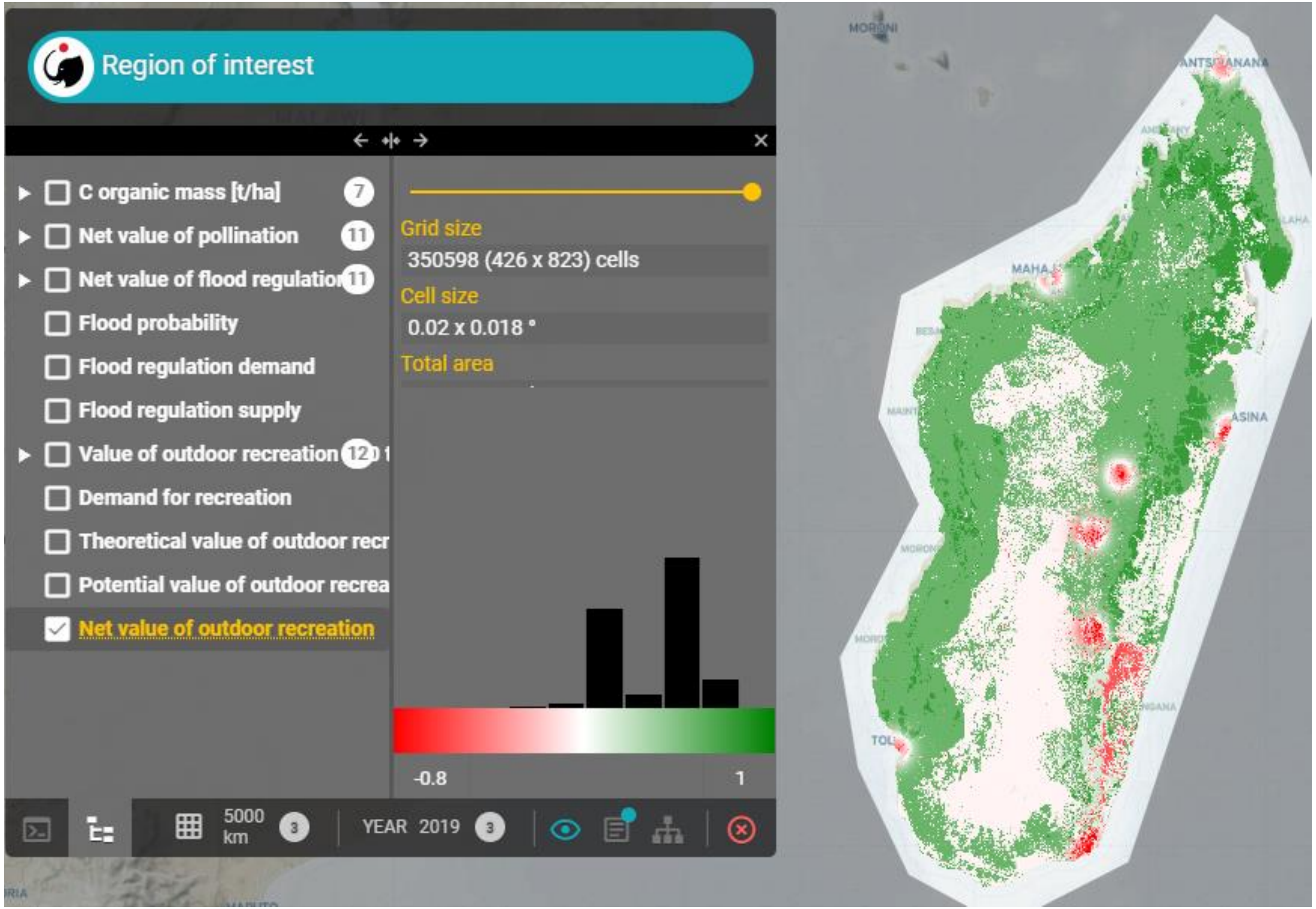
Region of interest
C organic mass [t/ha]
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Net value of pollination
11
Net value of flood regulation
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Flood probability
Flood regulation demand
Flood regulation supply
Value of outdoor recreation
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Demand for recreation
Theoretical value of outdoor recr
Potential value of outdoor recrea
Net value of outdoor recreation
Grid size
350598 (426 x 823) cells
Cell size
0.02 x 0.018 °
Total area
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1
5000 km
3
YEAR 2019
3
MORONI
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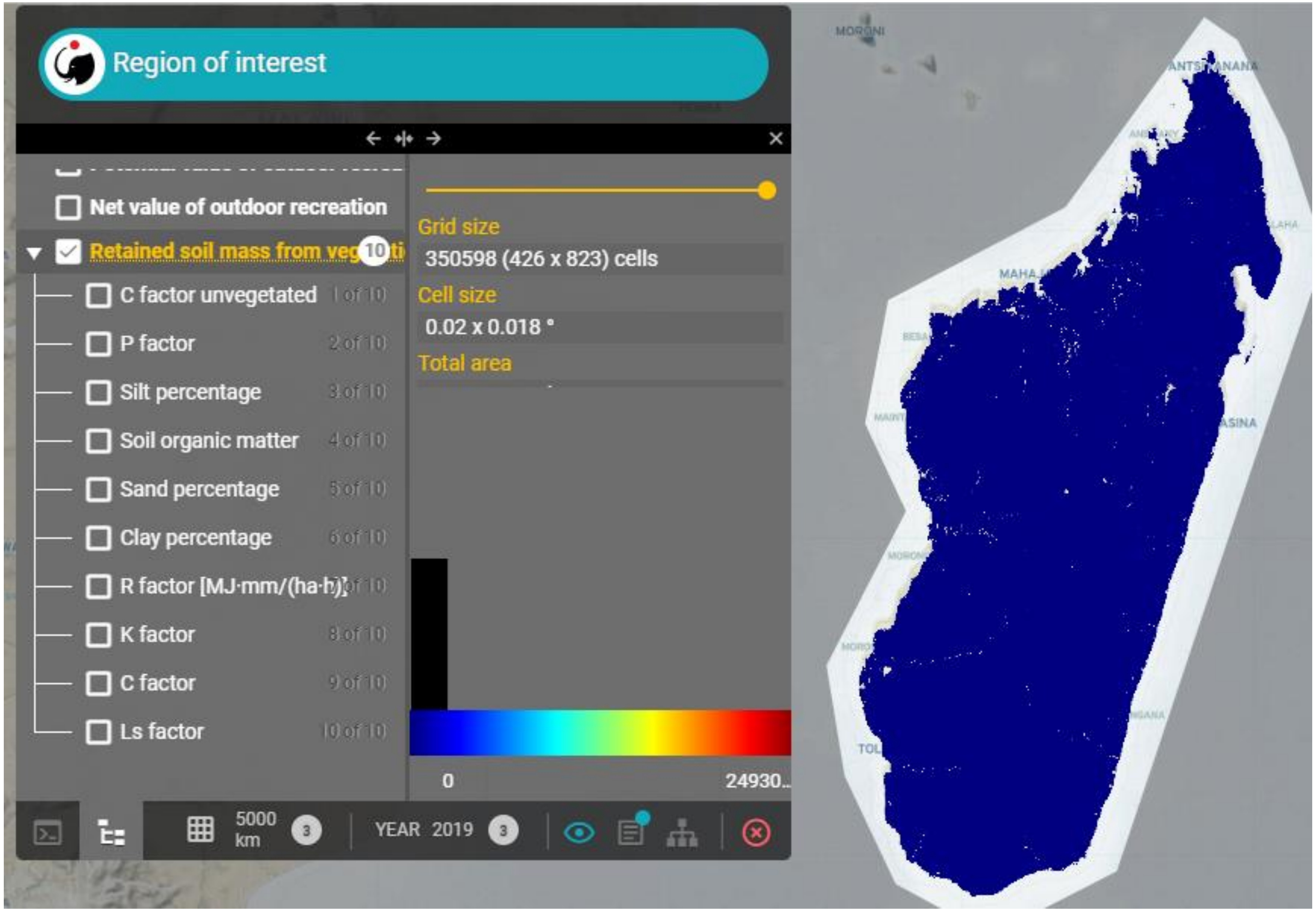
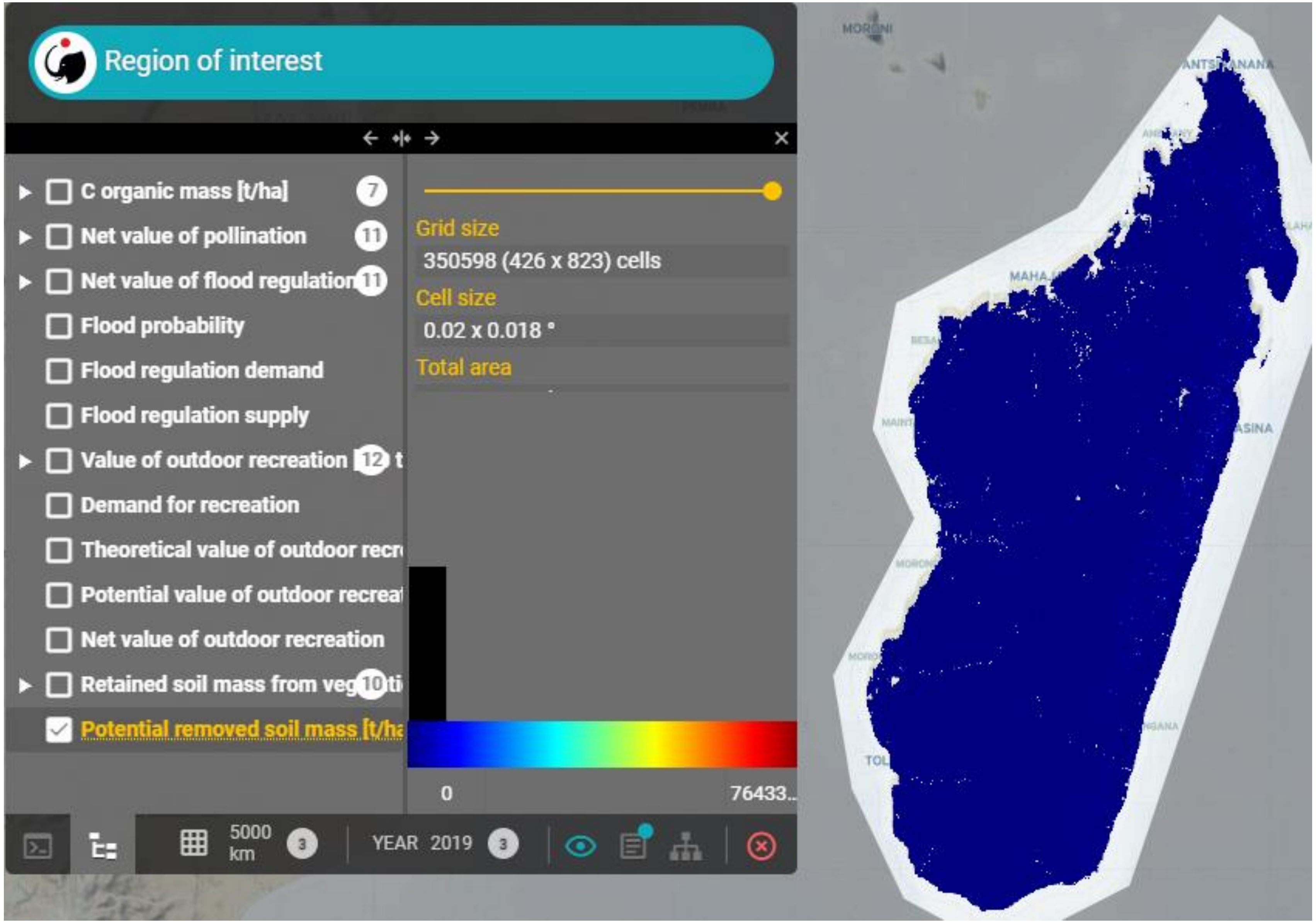
TOL

Sediment retention (5,000 km2, run time 10 min)




Region of interest
C organic mass [t/ha]
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Net value of pollination
11
Net value of flood regulation
11
Flood probability
Flood regulation demand
Flood regulation supply
Value of outdoor recreation
12
Demand for recreation
Theoretical value of outdoor recr
Potential value of outdoor recreat
Net value of outdoor recreation
Retained soil mass from veg
10
Potential removed soil mass [t/ha
Grid size
350598 (426 x 823) cells
Cell size
0.02 x 0.018 °
Total area
0
76433...
5000 km
3
YEAR 2019
3
ANTSIRANANA
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THANK YOU!