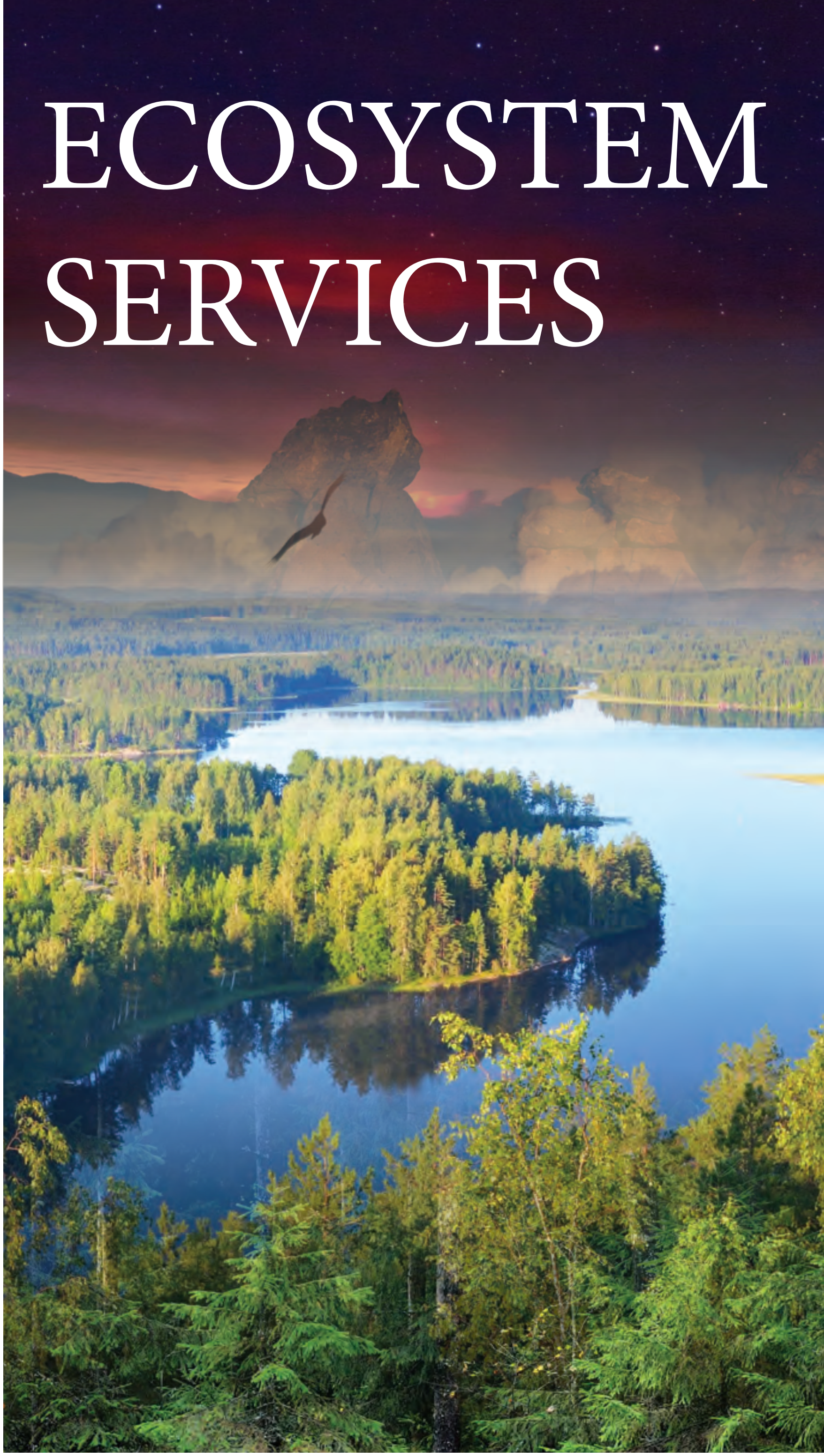

MAPPING ECOSYSTEM SERVICES

edited by
Benjamin Burkhard
& Joachim Maes

PENSOFT

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3.4. Tools for mapping ecosystem services

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Background

Mapping tools have evolved impressively in recent decades. From early computerised mapping techniques to current cloud-based mapping approaches, we have witnessed a technological evolution that has facilitated the democratisation of Geographic Information Systems (GIS). These advances have impacted multiple disciplines including ecosystem service (ES) mapping. The information that feeds different mapping tools is also increasingly accessible and complex. In this chapter, we review the evolution of mapping tools that are shaping the field of ES mapping together with the different sources of information that exist at this point. We discuss briefly the suitability of these approaches for mapping different ES types and for different scientific and policy aims. Finally, we elaborate on the integration of multiple tools (from desktop applications to sensor, web-based, or mobile devices) and on the future developments of these methods and the possibilities they may open for ES mapping.

Introduction

ES mapping has achieved rapid progress in a very short time frame. To our knowledge, the first peer-reviewed ecosystem service maps were published in 1996 and, since then, a large number of ad hoc mapping studies have been conducted and a variety of tools have been developed to systematise ES mapping. The progress we have witnessed corresponds to advances in computing power, modelling and GIS, the recognition of a plurality of ES approaches (i.e., participatory mapping (Chapter 5.6.2) and biophysical modelling (Chapters 4.1 and 4.4), and the consensus that ES maps provide a direct connection between ES and the landscape and therefore with policy (Chapter 7.1).

Description of main mapping software, tools and databases

Computing power and data availability that support GIS analysis have evolved substantially in recent years. Several freeware GIS platforms have been developed, such as QGIS (Quantum GIS), GRASS GIS (Geographic Resources Analysis Support System GIS), SAGA (System for Automated Geoscientific Analyses), and gvSIG (Generalitat Valenciana Sistema de Información Geográfica) that provide similar functionality to the popular commercial ArcGIS software from ESRI (a list of GIS software is available here[1]).

Specific modelling approaches for mapping ES have been developed by different institu-

[1] https://en.wikipedia.org/wiki/List_of_geographic_information_systems_software

tions worldwide, resulting in a wide variety of possibilities for ES analysts' use (Table 1, also see chapter 4.4). Most of these tools are openly available to the public and are constantly evolving. Training for the potential users of these tools is of importance for their accessibility and use for decision support. The operational time necessary for their application to case studies ranges from hours (simple spreadsheet-based tools) to several months (advanced software tools).

Table 1. List of the most common ES mapping tools.

Tool	Platform	Scale[2]	Source
Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST)	ArcGIS/Stand-alone	Municipal to provincial	http://www.naturalcapitalproject.org/invest/
Artificial Intelligence for Ecosystem Services (ARIES)	Graphical User Interface (GUI)/ Web-based	Municipal to provincial	http://aries.integratedmodelling.org/
Multiscale Integrated Models of Ecosystem Services (MIMES)	Simile software	Village/farm to global	http://www.afordablefutures.com/orientation-to-what-we-do/services/mimes
Social Values for Ecosystem Services (Solves)	ArcGIS	Municipal to provincial	http://solves.cr.usgs.gov/
Land Utilisation Capability Indicator (LUCI)	ArcGIS	Village/farm to provincial	http://www.lucitools.org/
Integrated Model to Assess the Global Environment (IMAGE)	Set of models	Global	http://themasites.pbl.nl/models/image/index.php/Welcome_to_IMAGE_3.0_Documentation
Co$ting Nature	Web-based, Google Earth	Municipal to provincial	http://www.policysupport.org/costingnature
Ecosystem Valuation Toolkit	Web-based	Municipal to provincial	http://esvaluation.org/
ESM-App	Android Smartphone app	Municipal to provincial	http://www.ufz.de/index.php?en=33303

The use of GIS in ES mapping can take three general approaches: (1) analysis tools built into GIS software packages; (2) disciplinary biophysical models applied for ES assessment (e.g., hydrological models such as the Soil and Water Assessment Tool, SWAT or Variable Infiltration Capacity model, VIC for water-related ES); and (3) integrated modelling tools designed specifically for ES assessment (e.g., InVEST, ARIES). The first approach is applicable for simple land cover-based analyses and indicator-based ES mapping (see Chapter 5.6.4) that have been used for example in Mapping and Assessment of Ecosystems and their Services (MAES). The second approach is appropriate for more complex model-based analyses of services that integrate expertise from specific disciplines (e.g., ecology for crop pollination or hydrology

[2] Malinga et al. (2015) define scales as follows: village/farm < 60 km^2; municipal 60-8,709 km^2; provincial 8,709-83,000 km^2; national 83,000-1,220,000 km^2; continental > 1,220,000 km^2.

for flood regulation mapping). The third approach extends the second one by utilising modelling tools that can assess trade-offs and scenarios for multiple services.

Several ecosystem service valuation databases have been developed as well, such as The Economics of Ecosystems and Biodiversity (TEEB) Valuation Database and the Ecosystem Valuation Toolkit and these might be used to create ES maps. The Ecosystem Services Partnership (ESP) Visualisation Tool is a database consisting of ES maps prepared by different researchers intended to promote synthesis of mapping studies (see chapter 7.9).

Applicability of mapping tools

In-depth assessment of the different mapping tools is necessary to understand which one will best fit the user´s ES mapping context: time and data availability, mapping skills, types of services to map, accuracy required, expected impact in decision-making and overall study aims. This means that no tool fits all criteria perfectly. Some highly complex models can provide policy support in regions with considerable time, data and personnel resources. Other approaches exist that allow ES to be mapped with more limited budgets and shorter time frames. The intended use of the maps (i.e., for raising awareness or direct use in policy-making) will also influence the decision on which tools to use (see Chapter 5.6.1).

In many cases, the type of ES under assessment will determine the mapping approach or tools to use. Services such as water regulation usually require modelling approaches that integrate meteorological databases, vegetation, soils and topographic data (Chapter 5.5.1), while others such as cultural identity might require a participatory mapping approach (Chapters 5.5.3 and 5.6.2). Other services such as food production might use complex agricultural models or indicator-based approaches (Chapter 5.5.2). However, the complex nature of ES and the inter-linkages between provisioning, regulating and cultural services have led to the use of different tools for each ecosystem service.
It is also important to consider how different mapping tools account for accuracy, reliability and uncertainty. Accuracy is established through successful calibration, reliability through successful application in different contexts and uncertainty through methods that estimate and transparently communicate uncertainty. These aspects have not been adequately covered in the past and still need to be developed for several tools. Greater transparency in the presentation of results and associated uncertainties (Chapter 6) is needed so that informed decisions can be made about the extent to which ES maps can be used for different purposes and which tools are best applied in different contexts and locations.

Future developments

Several challenges lie ahead for mapping ES. These are related to the progress that is currently underway in research and monitoring, remote sensing, sensor networks, data storage, data and knowledge integration, data harmonisation and sharing, database and tool maintenance and crowdsourcing, among others.

On the technical side, the accumulation of a growing quantity of data raises the challenge of effective storage and analysis of large amounts of data and is leading to an increased emphasis on machine learning, pattern recognition (in complex data or remote sensing products), and data mining. Initially high data storage requirements were addressed by large data storage and supercomputer facilities, but falling costs of distributed solutions have pushed computing towards scalable clusters of computers, grids and cloud computing, all aimed at increasing demand-driven computational power. Some ES modelling approaches using grids include: Tropical Ecology Assessment and Monitoring (TEAM) Network, Web-based Data Access and Analysis Environments for Ecosystem Services, ARIES, enviroGRIDS and biodiversity virtual e-laboratory (BioVel). The advantage of grids/clouds is that they are on-demand, self-service approaches, so the user can unilaterally obtain the necessary computing capabilities, such as server time and network storage, without having to interact with each service's provider. Cloud-based modelling tools and interfaces (e.g., OpenMI) will enable the joint development of and access to modelling and visualisation tools.

The ongoing development and maintenance of ES mapping tools (including free open-source software) require adequate funding. Further integration of ES mapping tools with policy will contribute to ongoing developments in the field and a tailored approach towards decision-making aims.

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