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Interreg
EUROPEAN UNION
Danube Transnational Programme
ECO KARST

Mapping of ecosystem services at the regional level

A practical guide

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Executive summary

Mapping of ecosystem services at the regional level

Ecosystem services (ES) are all tangible and intangible benefits that natural or human-modified ecosystems provide and which are vital for human wellbeing. The concept strives to capture the multi-faceted relation of interdependence between ecological and socio-economic systems in a simplified way. To achieve this, it borrows an analogy from the economy: a provider (the ecological system) offers various services to a beneficiary (society). A number of tangible and intangible goods and benefits that natural and semi-natural ecosystems (e.g., forests, grasslands, marine communities) provide to society are commonly referred to as ES, such as the timber of forests, the self-purification of water bodies, or the beauty of the landscape. Preserving the integrity and functionality of ecosystems is vital for the long-term sustainability of the supply of ES, and eventually, for sustaining human life and wellbeing. With growing understanding of this connection, ES have recently become one of the most important topics in science and policy.

Principles of the assessment of ecosystem services

Policy relevance

ES is an emerging domain. Its framework has only recently been established at the European level. The European Commission's working group on Mapping and Assessment of Ecosystem Services (MAES) has produced a series of reports[1] aiming to help EU Member States in their national mapping of ES, which is required by Action 5 of the EU Biodiversity Strategy to 2020[2]. Besides, a comprehensive knowledge base on ecosystem services and ways to use this knowledge in policy and decision-making has recently been published in the form of an online tool called the ESMERALDA MAES Explorer[3].

Interdisciplinarity

Lying on the boundary between the domains of natural and social science, ecosystem services are inherently interdisciplinary, and therefore cannot fit into the confines of any already established discipline. They integrate different types of existing knowledge, and thus offer a common platform between various fields of science and policy. Furthermore, they are suitable for translating the complicated processes and connections in nature into a simple language understood and spoken by many, thus providing opportunities for stakeholder engagement.

1 http://ec.europa.eu/environment/nature/knowledge/ecosystem_assessment/index_en.htm

2 http://ec.europa.eu/environment/nature/biodiversity/strategy/target2/index_en.htm

3 http://www.maes-explorer.eu/

Stakeholder engagement

Gaining knowledge about ES is a team effort in the broadest sense of the word. Nature's benefits are vital for us all, and in most cases multiple actors use the land in multiple ways at the same time. If we want to know what nature provides in a particular piece of land, knowledge of all these actors is relevant. Having a strong participatory element, we offer to guide the user through an iterative assessment actively relying on the local expert knowledge, since credibility and actual uptake of the results are only possible if all relevant stakeholders are involved.

Goals of this document

Operationalisation of ES in decision-making is still lacking due to methodological debates on ES assessment as well as knowledge gaps regarding the state of ES at local and national levels in most of Europe, and especially in the South-East European region.
These knowledge gaps create a strong demand for elaborating ES assessment methods that are easy to follow, produce comparable results, and offer representative and quantifiable indicators. This guide aims to contribute to the growing knowledge pool that could eventually meet these methodological demands. The guide leads the readers through an ES assessment process from identifying the most relevant services and stakeholders and creating a customized ecosystem map, to the mapping and economic valuation of the actual services.
However, standard, one-size-fits-all methods for ES mapping cannot be created for several reasons. Conditions in different regions in Europe vary significantly in terms of their geography, ecosystem types, land use, society and economy as well as their purpose of the assessment, the targeted scale and data availability, all of which has to be taken into account while modelling ES. Therefore, methods should be flexible and suitable for customizing. Also, following the principle of participation, models should have open entry points where the knowledge of local experts can be integrated. In order to give workable guidance, we provide a clear framework and the general logic of the assessment methods, as well as specific recipe-like solutions for the most frequent questions. The methods can be tailored to fit individual situations, as illustrated by some real case examples from the Danube region.

Target groups

This guide is most relevant to managers and administrators of (protected) areas, who would like to incorporate ES into their land use planning or monitoring schemes, and strengthen their cooperation with stakeholders active in their area. However, other users may also find the document useful, for example, local municipalities, NGOs or researchers. It is an advantage if the user has an already established social network in the area where they are considered credible and reliable.

Scale
We have adjusted this guide for assessments of multi-purpose landscapes at a regional scale, e.g., at the level of a national park or administrative territory of a municipality, where different types of land use are present. Multi-functionality of the landscape enables the integration of different knowledge systems, while this knowledge is still connected to the ground by experience. On a smaller scale (e.g., farm level), we suggest narrower but deeper analysis, while on a larger scale (e.g. national level) more generalized data are more useful.

Biogeographic region
We have developed the methods in the framework of the ECO KARST project[4], funded by the Interreg Danube Transnational Programme of the European Union. The project focused on karst protected areas of the Danube region, involving seven pilot areas from seven countries, where the methods were tested and applied. However, the guide can be used in other areas of similar scale in the Danube region or elsewhere.

Data needs
In most cases, the assessment of ES does not create new knowledge in terms of primary data. Instead, it integrates data already existing in different forms. What is new is the way these data are integrated, which reflects the knowledge and experience of local experts. In most cases, local biophysical and statistical data can be suitable. However, these data might not always be public in detail, for example, forestry management plans or local statistical data on livestock. Thus having official access to at least some of these databases (which is usually the case for administrators of protected areas) - or being trusted in the local community so that data can be made available for the study - makes the assessment much easier. Confidential treatment of personal data is a fundamental principle.

Document outline

The guide is divided into five chapters, in line with the five domains of an ES assessment. These domains reflect five relatively distinct parts of an ES assessment process, with differences also in disciplines underlying and methods required. Thus while being interlinked and built on each other as parts of the same assessment process, individual chapters can be used separately as well. All chapters share the same types of information, including the description of scientific background, goals, and the actual methods with detailed instructions, as well as the data and skills required to complete the task. Real case examples, challenges and suggestions for quality checks are based on a lot of discussions, testing, and learning in the ECO KARST project.

4 http://www.interreg-danube.eu/approved-projects/eco-karst

The five domains of the assessment and their main goals are the following (see also Figure 1):

1. Identification of ecosystem types and creation of an ecosystem type map
→ delineating the area to be assessed, selecting a relevant ecosystem type categorization and creating an ecosystem type map

2. Identification and prioritization of ecosystem services
→ exploring locally relevant ES by desktop survey and semi-structured interviews, selecting research priorities by prioritization of ES with selection criteria or preference assessment survey

3. Stakeholder identification and involvement
→ exploring power relations among stakeholder groups and analyzing social network of local stakeholders to find key players, communication gaps and patterns of sharing information

4. Mapping of ecosystem services
→ mapping ecosystem condition and ecosystem services with the rule-based matrix model, with detailed method description for indicators most frequently chosen in ECO KARST

5. Economic assessment of ecosystem services
→ estimating the net profit generated on the market by various (provisioning) ecosystem services

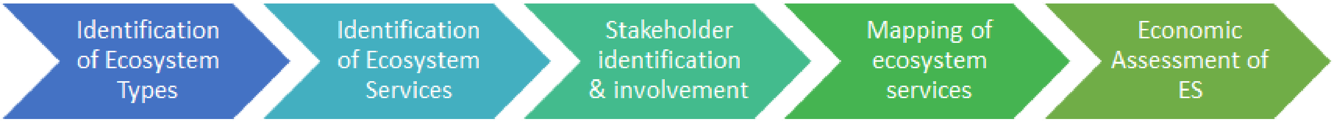

Fig. 1: The five domains of ES assessment

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Identification and mapping of Ecosystem Types

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Introduction

According to the UN (1992) definition, an ecosystem is "a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit". Different ecosystems are characterized by different processes and functions; they provide different ecosystem services and even in the case of the same service they usually have different potentials. Their state, heavily affecting their capacity to provide ecosystem services (ES), is defined by their use, which is also type-dependent. Therefore, any spatial assessment of ecosystem services should be based on a spatially explicit representation of ecosystem types (ET). Ecosystem mapping is the spatial delineation of ecosystems following an agreed ecosystem typology, which strongly depends on mapping purpose and scale (MAES 2013). Vegetation and habitat mapping have had a long history in Europe and, as a result, there are many available approaches and methods for both defining the typology and delineating the spatial units. There are also many existing typologies and maps at the European and the national level. The mapping and evaluation of different services rely on the ET map to a different level, therefore different spatial or typological resolution may be required according to the services to be assessed.

Goal of the document

The goal of this document is to assist in delineating the area to be assessed, the selection of a relevant ecosystem type categorisation and the creation of an ecosystem type map using the selected categorisation. Finally, it briefly gives some examples on what kind of data to look for when planning the mapping of ecosystem services in a karst area. However, the document does not cover methods of data acquisition (e.g. field mapping or remote sensing methods).

Place in the assessment process

This is the first document in a series of five guidance documents describing a participatory MAES process. The aim of ecosystem type mapping in this process is to provide the necessary spatial units and basic input for the ecosystem service assessment and mapping. Ecosystem types often serve as the basis of expert estimations in ecosystem service mapping.

Skills required to complete

The methods described here require only basic GIS skills and they are not software-specific – any software capable of adequately handling spatial data may be used. In the course of our work we mainly used ArcGIS (version 10.2), QGIS (version 2.14) and in some cases SAGA GIS (version 6.3).

Scientific background

Ecosystem type mapping – a short introduction

Ecosystem type mapping has a long history in Europe. The first such mapping were vegetation maps, made at the turn of the 18th-19th century. For a long time, such mapping served mainly scientific purposes. The first approaches were based mainly on the physiognomy of plants. Later more complex techniques were worked out where the floristic composition, the abiotic landscape elements and the dynamics were also taken into account. Most of the approaches put special emphasis on one or two of the above while also considering the other aspects, only to a lesser extent. All maps of vegetation or habitats are based on some system of classification.
From the beginning of the 1990s, the practical needs of nature conservation (management and policy) inspired the development of habitat mapping, which takes into account geographic, abiotic and biotic features. In Europe, adopting the EU Habitats Directive (92/43/EEC) led to the development of many mapping projects both at the national and the pan-European level (EEA 2014).

Existing maps and categorisations

European level

CORINE Biotope and Palaearctic habitat classifications
In the mid-1980s, the European Commission realized the need for an inventory of biotopes and started the work on creating a European-level classification of habitats within the frame of the CORINE (Coordination of Information on the Environment) project. The aim was to identify and map areas of high conservation values and to assess them within one framework. The resulting classification was published in 1991 (Devillers et al. 1991) and it became the basis for the selection of habitats listed in Annex I of the 1992 Habitats Directive. The CORINE classification was eventually extended to Central and Northern Europe, then to the entire Palaearctic region. As the geographical areas it covered became gradually larger, the underlying methodology had to be further developed. The Palaearctic habitat classification was published by the Council of Europe in 1996 (Devillers & Devillers-Terschuren, 1996) and a computer database tool (PHYSIS) was developed to support the work. The system is based on the matrix-use of the biotic realms of the I.U.C.N. bio-genetic reserve network system, and a list of habitats of global application. Through the application of a hierarchy of further divisions, where the elementary units were chosen to be as close as possible to entities recognized by local users, the system remained compatible with other local, national or international systems (PHYSIS home[1]).

1 PHYSIS Home: http://cb.naturalsciences.be/databases/cb_db_physis_eng.htm

European Nature Information System - EUNIS

Since both CORINE and the Palaearctic classification include little on marine habitats, and neither provides criteria for distinguishing the classes, the need for further improvement of European habitat classification was soon recognised. Its development started in 1995 by the EEA. The EUNIS habitat classification (Davies et al. 2004) is a 'comprehensive pan-European system to facilitate the harmonised description and collection of data across Europe'. Habitat type was defined as 'Plant and animal communities as the characterising elements of the biotic environment, together with abiotic factors operating together at a particular scale' (EUNIS home). The EUNIS system has a hierarchical structure[2], which consists of maximum 6 levels. Habitat types were characterised using a system of parameters, for example, substrate type, dominant lifeform, humidity, typical depth zone, human usage and impact (Moss 2008). However, criteria-based keys for definition are only given for level 3 and above (for terrestrial habitats). At level 4 and below, the units are based on other classification systems, which were combined in this common framework. EUNIS is proposed by the INSPIRE directive to be used as a common reference system in Europe. It has established crosswalks to other classification systems, both national and international[3,4].

ANNEX I of the Habitats Directive

In the Habitats Directive, natural habitats are defined as 'terrestrial or aquatic areas distinguished by geographic, abiotic and biotic features, whether entirely natural or semi-natural'. The habitats considered to be of European interest are listed[5] in Annex I of the Habitats Directive, which is thus a selective list of habitats of conservation interest[6] adopted for legislative purposes (Moss 2008). Annex I is not a comprehensive system, and there were also different issues in its implementation, which led to differences in interpretation between countries and regions (EEA 2014). Despite that, the use of Annex I habitats became popular in Europe due to reporting obligations and also because it provides a finer resolution for certain habitat types than the EUNIS classification.

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2 EUNIS hierarchical view: http://eunis.eea.europa.eu/habitats-code-browser.jsp

3 Crosswalk between EUNIS habitats classification 2007 and Palaearctic habitat classification 2001:
https://www.eea.europa.eu/themes/biodiversity/eunis/eunis-habitat-classification/documentation/link-eunis-and-palhab2001.xls

4 Crosswalk EUNIS – Annex I:
https://www.eea.europa.eu/themes/biodiversity/eunis/eunis-habitat-classification/documentation/link-between-eunis-2007-and.xls

5 Link to the hierarchical view of the Annex I classification: http://eunis.eea.europa.eu/habitats-annex1-browser.jsp

6 Interpretation manual of EU habitats: http://ec.europa.eu/environment/nature/legislation/habitatsdirective/docs/Int_Manual_EU28.pdf

Ecosystem type mapping for Ecosystem Service Mapping

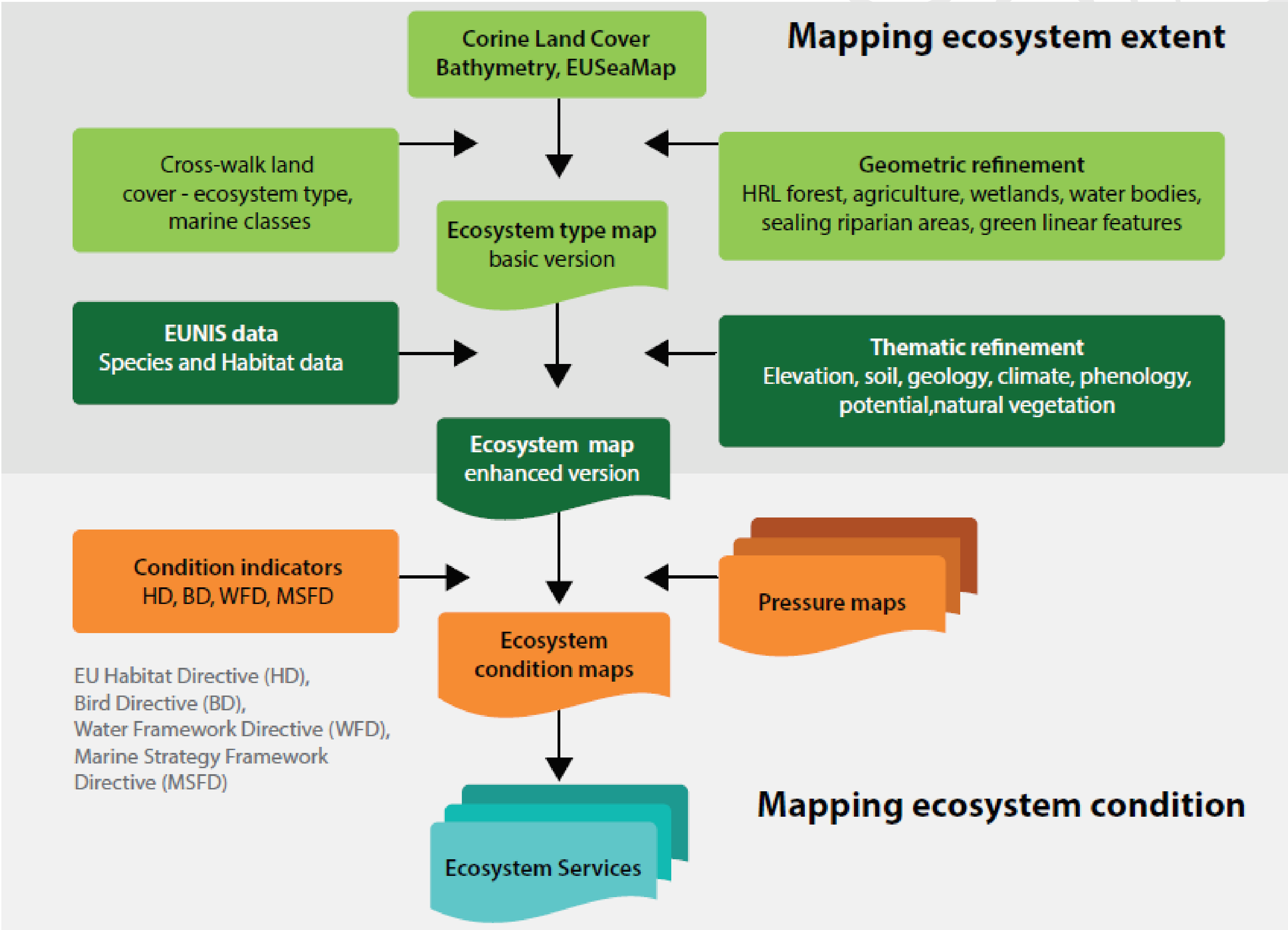

Fig. 1 The recommended workflow for ecosystem mapping and condition assessment in MAES (Maes et al. 2015)

Ecosystem type mapping in the MAES process

The mapping and assessment of ecosystems and ecosystem services is one of the key points of the EU Biodiversity strategy. In order to see this through, in 2012 the European Commission established its Working Group on Mapping and Assessment of Ecosystems and their Services – MAES. In their first report (MAES 2013) ecosystem mapping is defined as ''the spatial delineation of ecosystems following an agreed ecosystem typology (ecosystem types), which strongly depends on mapping purpose and scale.' It distinguishes two major approaches to ecosystem classification at a global level: typological or regional. The typological approach divides nature into broader ecosystem types (i.e., temperate broadleaf and mixed forests) whereas the regional approach describes ecosystems from a spatially unique perspective (e.g. Dinaric mixed forests). The MAES group advises to rely on existing and regularly refreshed data, and to have categories which 'represent the most important types of their human management to make best use of their services, e.g. by agriculture, forestry, fisheries, water management, nature protection or territorial planning.' (Maes et al. 2015). The method proposed for ecosystem mapping relies on CORINE Land Cover (CLC) classes to be aggregated into ecosystem types, combined with other, ecosystem-relevant information (Fig. 1).

The MAES proposal for level 1 and 2 corresponds directly with the EUNIS habitat classification (see Table 1). For further refinements, they suggest e.g. integrating more detailed information about rivers and lakes, green linear elements, such as hedgerows, or detailed maps of urban areas or protected areas (Maes et al. 2015).

Major ecosystem category (level 1)	Ecosystem type for mapping and assessment (level 2)	Representation of habitats (functional dimension by EUNIS)/MSFD for marine ecosystems)	Representation of land cover (spatial dimension)
Terrestrial	Urban	Constructed, industrial and other artificial habitats	Urban, industrial, commercial and transport areas, urban green areas, mines, dump and construction sites
	Cropland	Regularly or recently cultivated agricultural, horticultural and domestic habitats	Annual and permanent crops
	Grassland	Grasslands and land dominated by forbs, mosses or lichens	Pastures and (semi-) natural grasslands
	Woodland and forest	Woodland, forest and other wooded land	Forests
	Heathland and shrub	Heathland, scrub and tundra (vegetation dominated by shrubs or dwarf shrubs)	Moors, heathland and sclerophyllous vegetation
	Sparsely vegetated land	Unvegetated or sparsely vegetated habitats (naturally unvegetated areas)	Open spaces with little or no vegetation (bare rocks, glaciers and beaches, dunes and sand plains included)
	Wetlands	Mires, bogs and fens	Inland wetlands (marshes and peatbogs)
Fresh water	Rivers and lakes	Inland surface waters (freshwater ecosystems)	Water courses and bodies incl. coastal lakes (without permanent connection to the sea)
Marine	Marine inlets and transitional waters		
	Coastal		
	Shelf		
	Open ocean		

Table 1. The MAES categorisation of ecosystem types (level 1 and 2)

Customized category systems

National and regional ES mapping projects often use customized ecosystem typology r to best suit the characteristics of the habitats and the ecosystem services being assessed. One such example is the NIRAJ MAES project. Table 2 presents the habitat categories used in this project (Vári et al. 2017).

Habitat Category (ET)	Definition
settlement	villages, outer areas with gardens and single farms
intensive agricultural	intensive, large arable fields (patches >10 ha)
extensive agricultural	mixed agricultural mosaic of small patches of various uses (patches <10 ha)
pasture	pastures, grazed grasslands of different degrees of degradation
hay meadow	hay meadows
encroached grassland	shrublands, abandoned grasslands encroached with shrubs
wood pasture	solitary trees in grassland patches
orchard	abandoned or extensively used fruit tree plantations/vineyards
tree row	group of trees/small forests/tree rows/galleries along small valleys
pine and spruce forest	native coniferous plantations
mixed forest	native deciduous and coniferous mixed forest
broad-leaved forest	deciduous forests of native tree species
plantation	plantation of non-native tree species
wetland and water	major rivers, lakes and fisheries, including the reed banks

Table 2: example for Ecosystem Type definitions in the Niraj MAES project

Boundary definition of the pilot area

The area to be included in the analysis needs careful consideration. It should provide many ecosystem services to the communities living within and around it. Ideally, a pilot area should be a complete social-ecological system. Ecosystem structures and processes that provide a specific ecosystem service at a particular spatial scale are called service providing units (SPU) (Luck 2009). The places where humans use ecosystem services are called service benefitting areas. When making a decision on the boundary of the pilot area, it is important to consider that there is often a spatial mismatch between the service providing and benefitting areas (Brauman et al. 2007). Certain types of data may only be available for parts of the total area – e.g. habitat type maps are usually created for the more natural areas whereas these may provide services for the population of a wider area.

The expected outputs from this task are shapefiles of the boundaries of the planned pilot area.

Data needs

- Maps of the relevant administrative or other units (e.g. boundary of the protected area or geographical region)
- Footprints or bounding boxes of the available datasets are useful, as data availability is a crucial issue

Workflow

Delineation of the pilot area consists of two main steps and results in two or three types of areas:

(1) A general "focus area" is defined on the basis of a systemic approach: the selected area is preferably not defined by administrative boundaries but represents a whole social-ecological system. This means that both ecological boundaries and connected social systems are taken into account, and communication can be maintained with all relevant stakeholder groups.

(2) The "core area" is the service providing area within the focus area. The selected area has to be large enough to offer a meaningful understanding of the flow of ecosystem services, but small enough to be studied with the resources and workforce available. It is crucial to have spatial information about the ecosystem types within the core area.

(3) The "buffer area" is that part of the focus area which is not included in the core area. Designating a buffer area is not a necessity but an option to resolve the problem of service providing areas being spatially separate from service benefiting areas. The relevant stakeholder groups should be involved in the ecosystem service assessment process even if they are located outside of the core area.

If it is unclear what the service benefiting areas may be, the extension of the core area can be carried out based on the stakeholder analysis. What are the social boundaries of the protected area? Which settlements are in close cooperation with it, where are the most active stakeholders? Stakeholder communication is highly influenced by location, thus conducting the social network analysis described in the third chapter may help to find the social boundaries of the protected area.

After making the decision, the actual delineation can be carried out by merging the relevant spatial units or, if data is available only for part of the administrative or geographical region of interest, by defining the intersecting area of the available spatial datasets and the region of interest. Before carrying out any geoprocessing, it is important to check that the input databases (if more than one are used) use the same coordinate system. Topological errors should be checked for and corrected.
When dealing with multiple areas in different countries, it can be useful to define a common coordinate reference system to be used throughout the mapping process. In the course of our work, we used WGS84 (EPSG:4326). We chose this as it is a widely used standard and as such can easily be converted to any other (local) system. Another useful alternative is the ETRS89 Lambert Azimuthal Equal-Area projection coordinate reference system, which is widely used with pan-European databases.

Challenges

In some cases, boundary definition may present a considerable challenge due to the spatial separation of service providing and benefitting areas. Distinguishing buffer and core areas is a practical solution to this.

Quality check

Quality issues would rarely emerge during this step unless there is a problem (e.g. topology errors, outdated administrative units, etc.) with the input data.

Examples

As is often the case with karst areas, many of the stakeholders relevant to Bükk National Park live and work outside the protected area, in the foothill regions. Figure 2 shows those areas that were originally chosen as buffer zones – these areas were not mapped but were included in the stakeholder analysis.

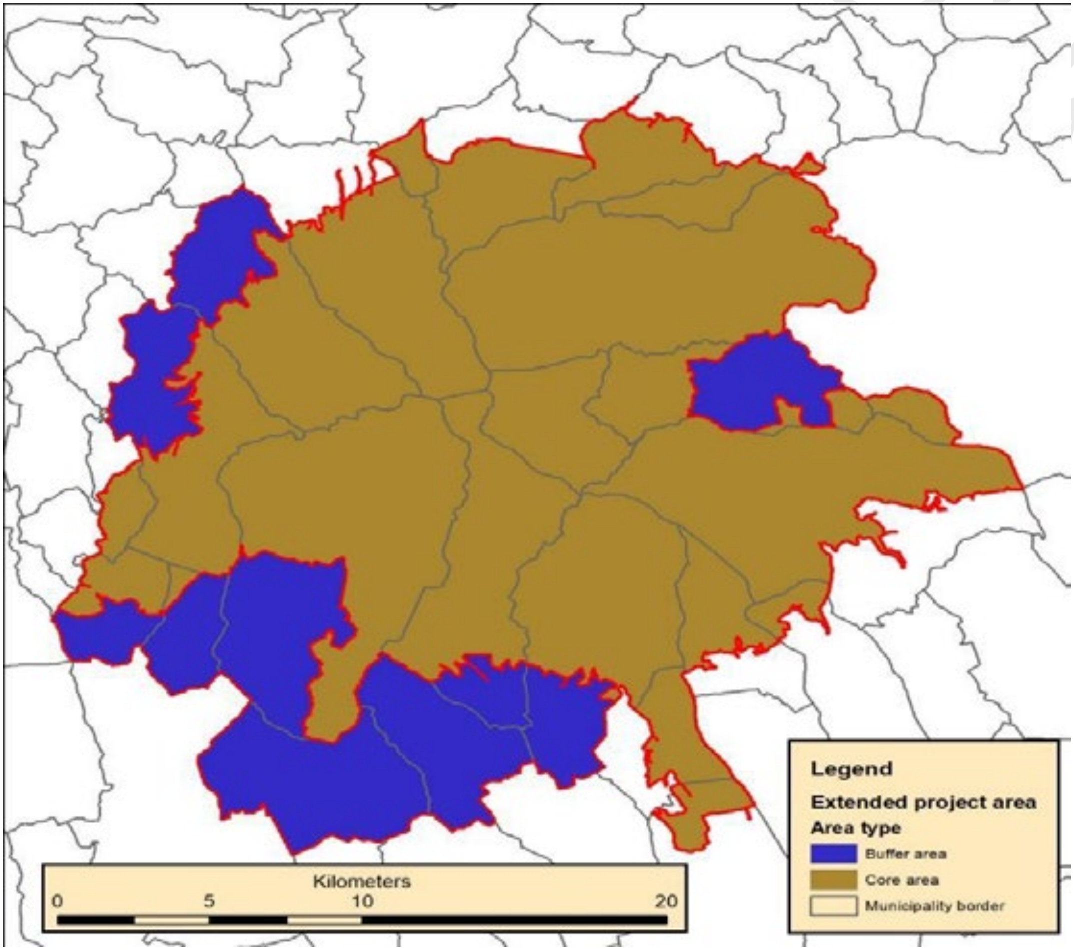

Fig. 2 Sample map of Bükk National Park (by András Schmotzer)

Ecosystem type definition

When planning an ecosystem services study, one could either begin with identifying ecosystems in the study area and then determining which services they provide or alternatively, begin with identifying priority services and then determining which ecosystems are most likely to provide them. Either approach requires an understanding of which ecosystems provide which services (Bordt and Saner 2019). Furthermore, whenever an ecosystem service assessment involves more than one country (different in terms of ecosystem types, data availability, data structure, etc.) it is very important to try to ensure the consistency and comparability of the results. Thus, there is a need to use a common classification at least at the higher levels of the classification hierarchy. The expected output is an ecosystem typology (basically a list of ecosystem types and their definitions), which is consistent over the relevant area(s) and is suitable to serve as the main input of the planned ecosystem service assessment. On the other hand, it is also important to take into consideration that local experts are more likely to be able to relate to locally used habitat classification systems and information (including data, models, characteristics, etc.) may be more readily available for these categories.

Data needs

This step involves data only indirectly – there is always the possibility to create a completely new categorisation, but most often the categories need to be adjusted to already existing databases. For a list of such databases, see the next section on ecosystem type map creation.

Workflow

Some general guidelines to find the relevant Ecosystem type (ET) categorisation:

- the categories should be distinct enough so that there are no uncertainties as to where any spatial unit belongs
- the categories should be clear enough for the local experts to be able to work with them at later stages of the assessment process
- the number of categories should be near the minimum necessary to carry out the mapping and evaluation of the ecosystem services
- the categories should be fine enough to be meaningful for assessing the relevant ES. When studying a smaller but variable area (as karsts often are), over-generalization can lead to a loss of important information. Ecosystem/habitat types that are very different in ES supply should be separated on the map; types that are only marginally different can be handled as ‘‘sub-types’’ or merged during the evaluation process
- the categories need to represent all (karst-)specific ecological features

An ecosystem type map can be produced, in most cases, by compiling and converting already existing datasets. Therefore, the first step is identifying already existing habitat maps or other databases and examining whether their categories are suitable for ES assessment. If they are not, the next question is how the categories of the available databases can be modified to fulfill the needs of the ES assessment. The ideal level of refinement depends on what ecosystem services are chosen for mapping. For example, if there are detailed forest management plans and carbon sequestration is the ecosystem service to be assessed, broad categories (like e.g. EUNIS level3) suffice for most major ecosystem types (e.g. grasslands, arable lands), but the forests could be represented with more detail (e.g. EUNIS level 4). It is useful to use a multiple-level categorisation, which can be flexibly adapted to different needs. Even if an already existing categorisation is applied, in the case of specific habitats, customized categories can be locally introduced to avoid information loss or help local experts make estimations.

Challenges

As there are several contradicting requirements (simplicity vs suitability for assessment; relying on locally used classification systems vs comparability between the studied areas) it is not always easy to find the optimum level of refinement. Ideally, categories are best defined while choosing the relevant ecosystem services. In the course of our work on ecosystem type mapping within EcoKarst, we have encountered two major challenges : (1) when dealing with multiple pilot areas in different countries data availability and the structure of available data inevitably differs between countries (2) the input requirements may differ for the different services and thus the category system and scale of the ecosystem type map need to be chosen carefully.

Examples

Considering that several European countries were involved in the EcoKarst project, we decided to use a classification that can be easily adapted in any of them. The EUNIS classification, also suggested by MAES for such purposes, seemed suitable. EUNIS level 2 maps are available online for the whole of Europe[7] at a spatial resolution of 100 x 100 m. Most project partners already had some kind of a habitat map, which could be converted into a more detailed EUNIS classification. However, due to differences in national habitat mapping methods and categories, including data availability, the EUNIS hierarchical level we were able to produce based on the existing vegetation or habitat maps differed between pilots, e.g. in the case of certain pilot areas we were able to produce a categorisation at level 3, while in some others only level 2 was feasible (Table 3). In some cases, the levels were mixed, according to the available information, which often differed across major ecosystem types.

7 https://www.eea.europa.eu/data-and-maps/data/ecosystem-types-of-europe

Ecosystem type map creation

If a suitable database is available with the required categories, this step can be skipped entirely. If there is no such database or map, the ecosystem type map creation may be carried out parallel with forming the final categories. The expected output is an ecosystem type map (in the case of EcoKarst the requirement was to produce a shapefile or geodatabase feature layer in WGS84 projection), which contains the categories of the chosen ecosystem typology (in our case, EUNIS level 3 or 2) as attributes for each spatial unit.

Data needs

- Local habitat type maps, if available
- If habitat type maps are not available or do not cover the whole area, or their spatial resolution is not appropriate, other national (and/or European, if relevant) databases can be used to create ecosystem type maps, such as
  - Land use/land cover maps (e.g. CORINE Land Cover or more detailed local maps)
  - forest inventories
  - other products from the Copernicus Land Monitoring Service [8]
  - OpenStreetMap[9] databases
  - European Atlas of Forest Tree Species[10]
  - ...

Workflow

If an existing database is used, with the required categories, this step can be skipped entirely. After considering the available datasets and defining the ecosystem typology to use, the general principles of actually creating the ecosystem type map are fairly simple. First, the already available information (e.g. existing vegetation/habitat maps) should be assembled. Before carrying out any geoprocessing, it is important to check that the input database (or databases if more than one are used) use the same coordinate system. Topological errors should be checked for and corrected. Then, in order to create a EUNIS map, **a conversion table** is needed, where each original class is assigned a EUNIS category. The conversion table is not the same as a crosswalk, because in a crosswalk the relationship between the categories is often many to many (n:n) rather than one to many (1:n) or one to one (1:1) - although the existing crosswalks can be useful in creating the conversion table. Each row of the conversion table should correspond to one category of the existing vegetation/habitat classification that needs to be converted into EUNIS. **The compilation of a conversion table itself is not a GIS task. It**

8 https://land.copernicus.eu/

9 https://www.openstreetmap.org

10 https://forest.jrc.ec.europa.eu/en/european-atlas/

requires a thorough knowledge of habitat types and classifications. It is very important that

- each class of the original classification can only appear once in the conversion table
- each class of the original vegetation or land use map should appear and have an EUNIS equivalent in the conversion table
- the conversion table needs to contain the codes of the existing vegetation in exactly the same format as they appear in the original map's attribute table
- the EUNIS codes should be entered precisely.

The conversion table can be created directly in a GIS software or any spreadsheet-handling software e.g. Microsoft Excel or similar (recommended formats are xlsx, dbf or csv). For example, see Table 4.

Annex I code	Annex I name	Relation	EUNIS code	EUNIS name
6210	Semi-natural dry grasslands and scrubland facies on calcareous substrates (Festuco-Brometalia)	<	E1.2	Perennial calcareous grassland and basic steppes
6230	Species-rich Nardus grasslands, on silicious substrates in mountain areas (and submountain areas in Continental Europe)	#	E4.3	Acid alpine and subalpine grassland
6240	Sub-Pannonic steppic grasslands	<	E1.2	Perennial calcareous grassland and basic steppes
6250	Pannonic loess steppic grasslands	<	E1.2	Perennial calcareous grassland and basic steppes
6430	Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels	#	E5.4	Moist or wet tall-herb and fern fringes and meadows
6440	Alluvial meadows of river valleys of the Cnidion dubii	<	E3.4	Moist or wet eutrophic and mesotrophic grassland
6510	Lowland hay meadows (Alopecurus pratensis, Sanguisorba officinalis)	<	E2.2	Low and medium altitude hay meadows
6520	Mountain hay meadows	<	E2.3	Mountain hay meadows
7230	Alkaline fens	=	D4.1	Rich fens, including eutrophic tall-herb fens and calcareous flushes and soaks
9110	Luzulo-Fagetum beech forests	<	G1.6	[Fagus] woodland
9130	Asperulo-Fagetum beech forests	<	G1.6	[Fagus] woodland
9180	Tilio-Acerion forests of slopes, screes and ravines	<	G1.A	Meso- and eutrophic [Quercus], [Carpinus], [Fraxinus], [Acer], [Tilia], [Ulmus] and related woodland
91E0	Alluvial forests with Alnus glutinosa and Fraxinus excelsior (Alno-Padion, Alnion incanae, Salicion albae)	#	G1.1	Riparian and gallery woodland, with dominant [Alnus], [Betula], [Populus] or [Salix]

Table 4 Example of a conversion table – Annex I to EUNIS

The decisions should be documented for further reference. If the conversion table is ready, it needs to be joined in a GIS software to the original habitat map, based on the codes of the original classification and saved or exported so that the resulting map contains both the original categories and the new ones for each polygon. It is useful to keep the original polygon boundaries and categorisation in case further refinement is needed or if the local experts in the course of the work prefer to rely on the original categories.
It is possible that the whole area is not covered by one dataset but it can be mosaicked from multiple sources. In this case, the level of refinement should be the same for the whole core area at least across major ecosystem types. The age of the datasets is also an important factor to consider, they should not be very different and should all be as recent as possible.

Challenges

It may be tempting (and even logical) to use already existing pan-European datasets. However, the proper scale should be considered carefully - if the ecosystem type map used for the analysis is over-generalized, the results of the analysis can be misleading. Karst surfaces are especially variable spatially which results in very mosaic vegetation patterns, often further complicated by diverse land use. Since most countries have their own vegetation mapping protocols and categorisations, even if there is a detailed habitat map in existence, the actual process to turn these into a unified (EUNIS-based or other) categorisation is likely to be unique in the case of each area. In some cases there are existing crosswalks between different categorisations, but even when using EUNIS, an entirely new crosswalk may need to be created. Defining the equivalent of the national categories requires expert knowledge.

Quality check

The quality of any ecosystem type map will be defined by whether the appropriate method was used at the appropriate scale for the specific purpose of the mapping. The database should not contain any topological errors (e.g. overlapping polygons or gaps).

Examples

Bükk National Park (Hungary)

In the case of the Bükk Mts, a very detailed habitat map, based on the Hungarian national classification (ÁNÉR), was available. This map covers almost the whole area but so far, no direct conversion exists between ÁNÉR and EUNIS. We could have directly defined the corresponding EUNIS category for each vegetation type by simply filling in an Excel sheet using expert knowledge. However, there is an existing crosswalk between ÁNÉR and Annex I habitat classification (the dataset provided by the Directorate of Bükk National Park already contained the Annex I codes) and also between Annex I and EUNIS. Therefore, in order to ease our task and also to adapt to already existing work, we chose the Annex I classification as a means of transition between the two types of categorisation. Since most project partners reported having Natura 2000 maps, we chose to demonstrate this approach, as it could be applied in most of the pilot areas. Fig. 3 shows the steps of the workflow.

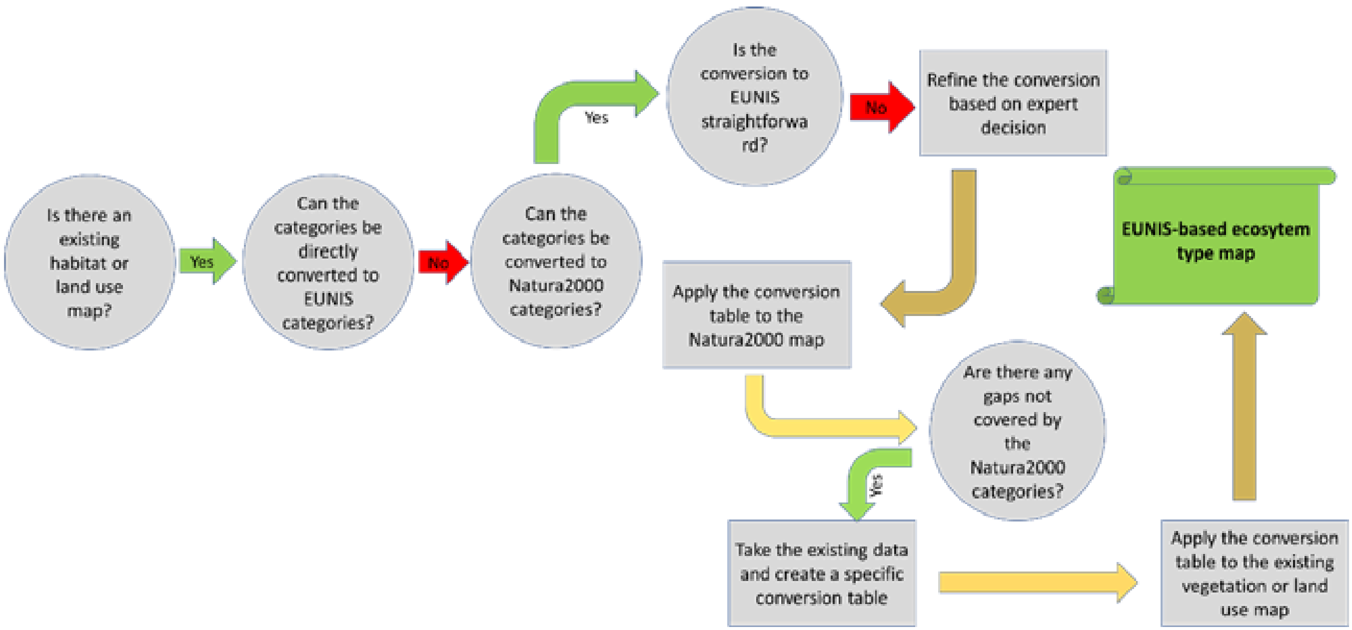

Fig. 3 Sample workflow for the Bükk NP pilot

First of all, we downloaded the official Annex I - EUNIS crosswalk to help create the conversion table. The crosswalk contains the name and code of the Annex I category and the code of the corresponding EUNIS categories at different levels, according to the best correspondence. Information about the relation of the two categories is also included. There are 4 types of possible relations (Fig. 4):

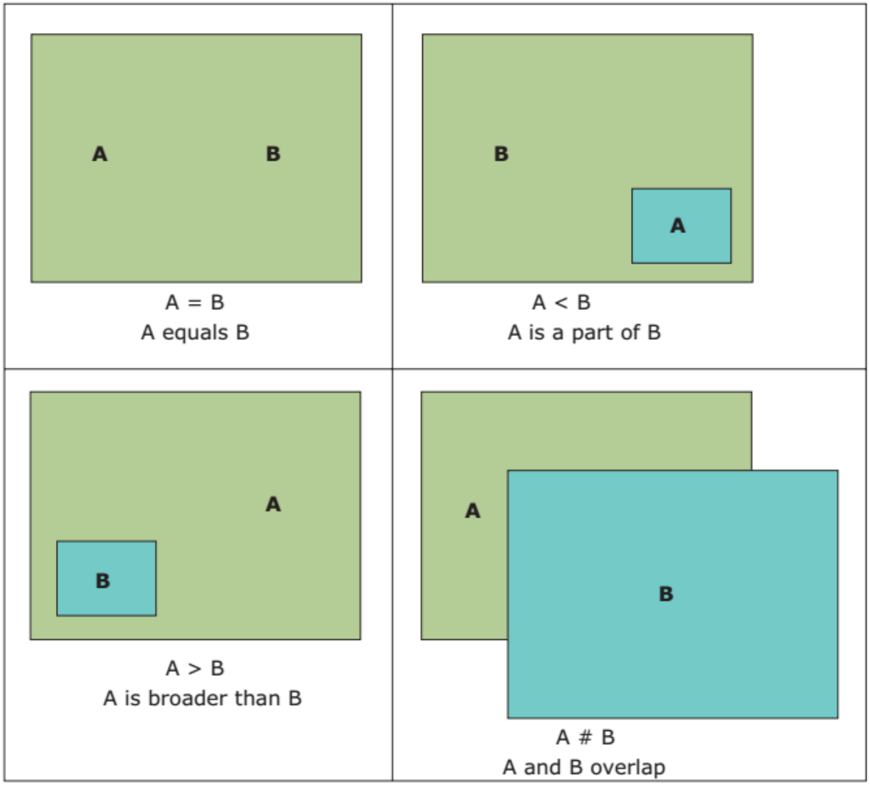

Fig. 4 (Source: EEA Technical report No 1/2014 - Terrestrial habitat mapping in Europe: an overview)

If the Annex I class is not the same as the EUNIS category, special attention must be paid so that the conversion does not give a false result and no information is lost. It is important to note that the crosswalk is not suitable for a straightforward conversion as it is, there are several Annex I categories which have more than one possible corresponding EUNIS category. It needs to be filtered before use,   and correspondences checked by an expert before the final conversion.

Examples of more than one EUNIS categories corresponding to one Annex I category

In the Bükk dataset, the Annex I habitat category 6430 can be either E5.4 (Moist or wet tall-herb and fern fringes and meadows) or E5.5 (Subalpine moist or wet tall-herb and fern stands) at EUNIS level 3. In such a case the descriptions of categories should be checked and the best correspondence chosen – the other deleted. Another solution is to merge the two categories, if decision cannot be reached. The original Hungarian ÁNÉR category is the D5, tall-herb vegetation of stream banks and fens. After some consideration, we chose the EUNIS category E5.4 and deleted E5.5.
Another example is 91E0, a completely different case. The Annex I category is too broad and encompasses two different ÁNÉR habitats. In this case, the solution is to use the original ÁNÉR classes to differentiate in a later (refinement) stage of the process. After the conversion table is created, it can be applied to the map. Fig. 5 shows the result.

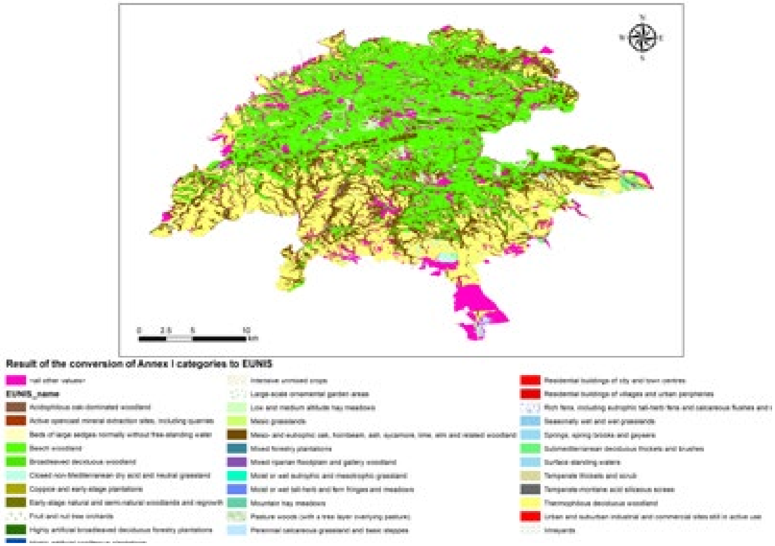

Fig. 5. First result of conversion through Annex I types

Refinement stage: Dealing with error and non-Annex I polygons

In the case of the Bükk Mts, the original ÁNÉR map provides almost a complete coverage, meaning that there are few gaps within the area where the habitat mapping took place. However, there are quite a few categories which are not Annex I habitats and therefore have no correspondent EUNIS classes after completing the above process. These are the NULL values in Fig. 5. In the example dataset, the habitats that have no Annex I class are mainly acidophilous forests, conifer plantations, human settlements and those habitats which could not be well defined due to their bad condition. These should be converted separately. This is the stage when the already converted categories can also be refined. Fig. 6 shows the result of the refinement.

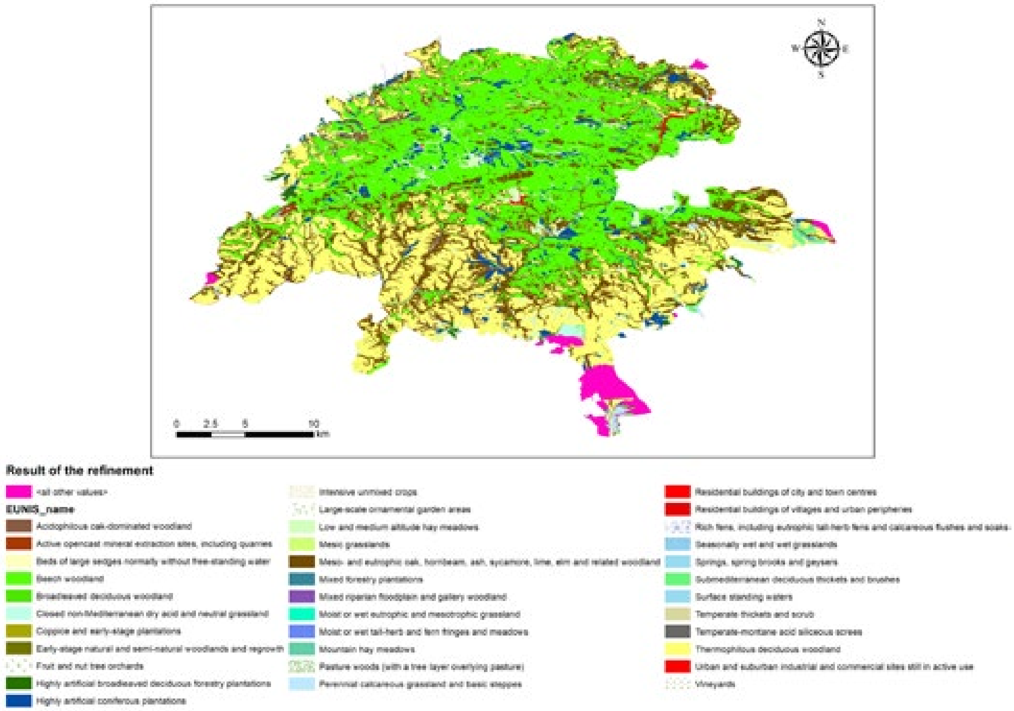

Fig. 6 Result of the refinement. The remaining NULL values show data gaps, which were filled in by applying other datasets (e.g. Corine Land Cover, forestry data, remote sensing data, etc.) and expert knowledge.

Notranjska Regional Park (Slovenia)

In the case of Notranjska Regional Park, a very detailed habitat map (using the Slovenian classification system) was available but only for a small section of the Park, around Lake Cerknica (Figure 7). Different databases were available for the remaining sections of the park.. A detailed inventory of forests was provided by the Slovenian Forestry Service including the delineation of spatial units (stands and compartments) and information on the stands for each of these (Figure 8). EUNIS categories for each unit were approximated based on the tree species composition.

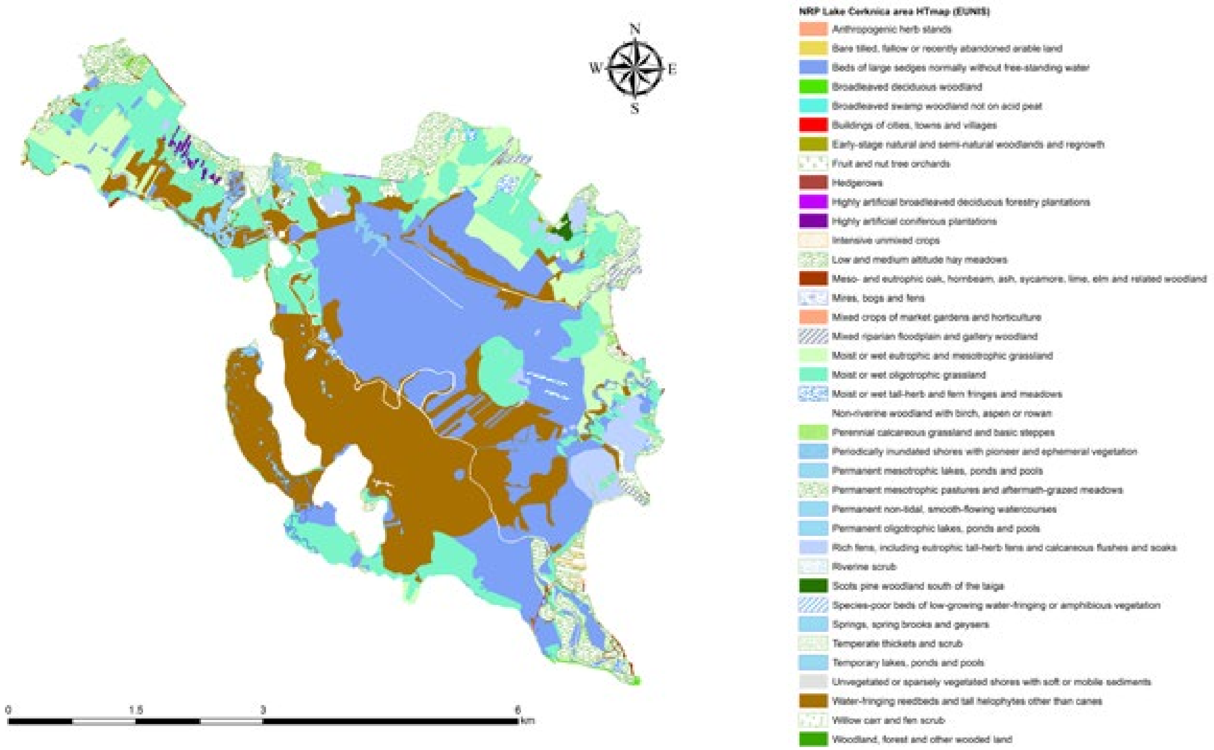

Fig. 7 Habitat type map of Lake Cerknica and its surroundings

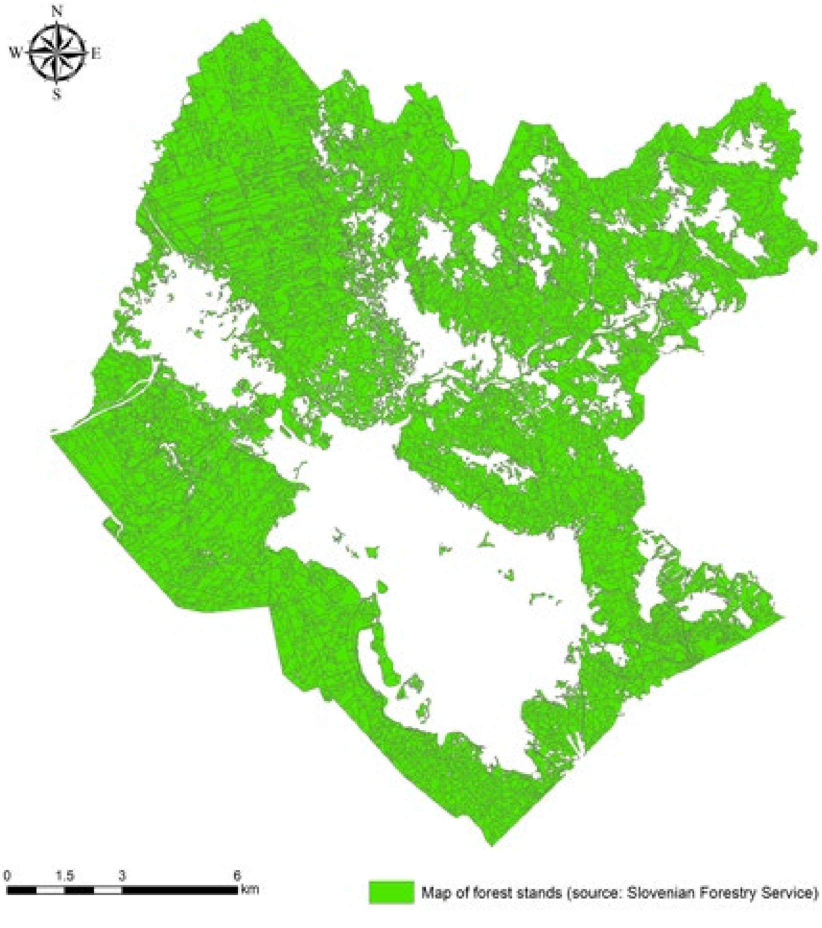

Fig. 8 Forest stand map of NRP (from the Slovenian Forestry Service)

For the rest of the area, the Agricultural and Forestry Land Use Database (RABA) (Figure 9) and the Register of Graphical Units of Land Use (GERK) databases were used, the latter established related to the reporting and controlling of EU direct payment to farmers in Slovenia.

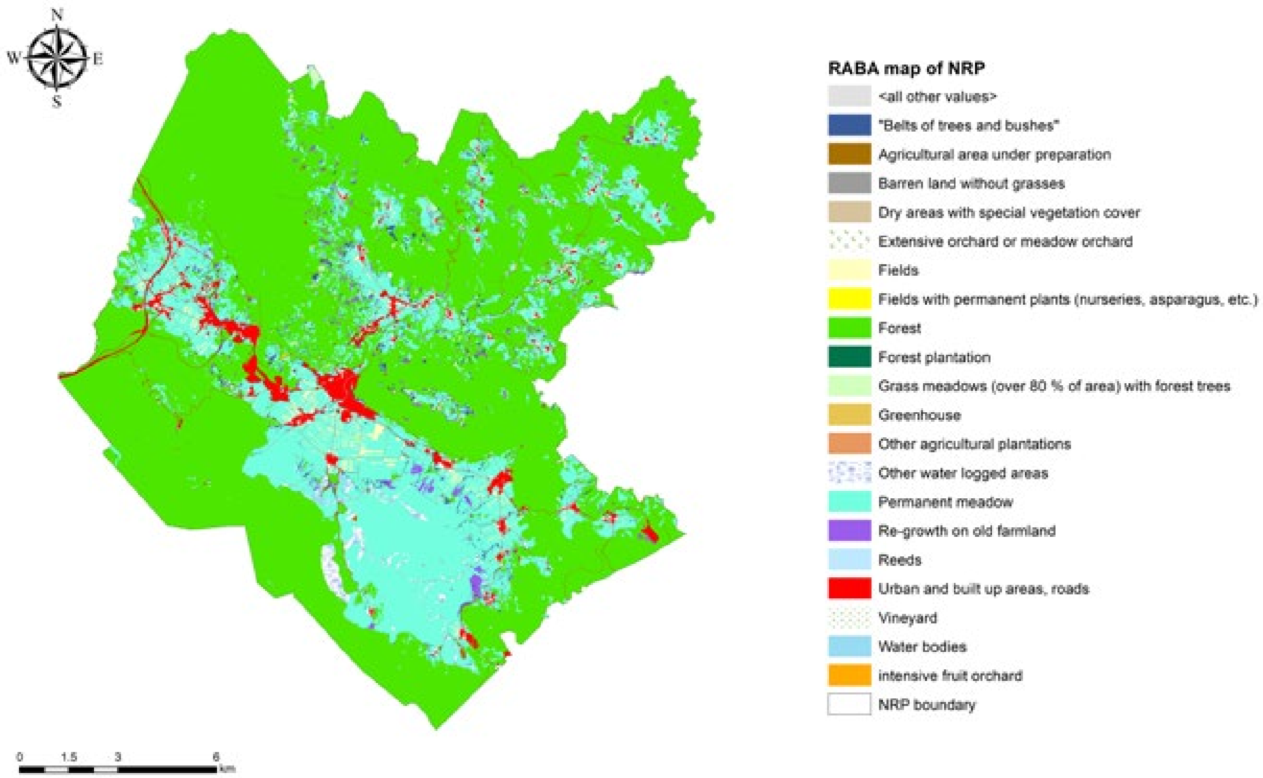

Fig. 9 The RABA map of NRP

These are spatially very detailed but being land use databases and not habitat type maps, the conversion into corresponding EUNIS classes was in some cases a challenge. Some categories were suitable only for defining the main ecosystem type (e.g. grassland). Expert knowledge (local) was used to further refine the categories, especially in the case of grasslands. The final map is shown in Figure 10.
It is important to note that such a detailed category system will most likely not be used in the course of ES mapping. However, a more detailed map provides more opportunity to customize the categories according to the specific needs of the ES being mapped.

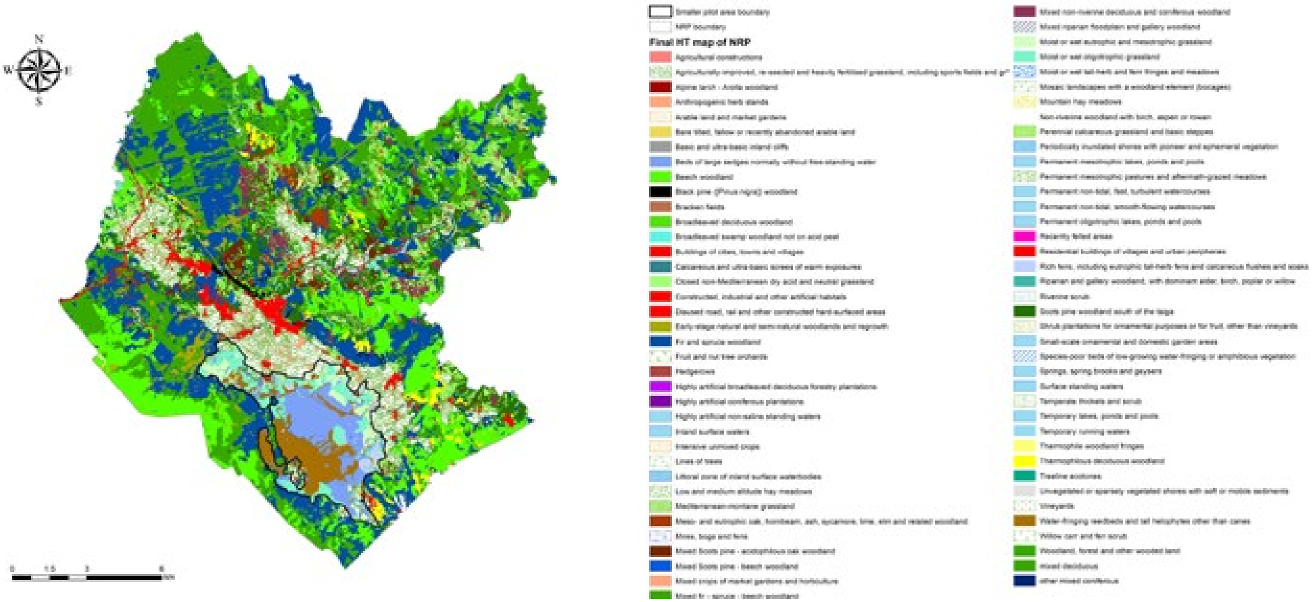

Fig. 10 The final ecosystem type map of NRP

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Identification of Ecosystem Services

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Introduction

The selection of ecosystem services (ES) and the indicators to measure them is a crucial step in any ES assessment. In order to ensure the uptake and use of its results, the research priorities of the ES assessment need to reflect what is regarded relevant in the study area. This is especially true if there are limited capacities available for the assessment, so that only a small number of ES can be mapped and assessed, and the most important ones need to be chosen. There are several major factors that we have to take into consideration during the selection of ES, such as:

- biophysical characteristics, dominant land use and economic activities of the area
- policies, strategies, and plans that influence land use and the supply of ES
- The preference of local stakeholders
- conceptual considerations and MAES recommendations
- data and methodological limitations

Purpose

In this document, we introduce methods of identification, prioritization, and selection of ES for a regional ES assessment. Thus, the subjects of the actual ES mapping are identified.
This guide was developed and tested in the ECO KARST project[1]. The project focused on karst protected areas in the Danube region, so certain ecosystem types and services - such as the entire marine - were out of its scope. A list of ecosystem services identified in ECO KARST is presented in detail. While the principles of ES identification and selection described here are completely transferable in areas outside the Danube region, the ES list is most useful in regions of similar scale and character: rural areas on the mountainous landscape, dominated by forests, grasslands, small scale agriculture, and freshwater.

Place among other GPs

After identifying the ecosystem types and creating an ecosystem type map of the area (as described in Chapter 1), an essential step of the Mapping and Assessment of Ecosystem Services (the so-called MAES process) is the identification and prioritization of the most important ecosystem services in the concerned area. The methods described in this guide have strong participatory components, requiring the identification and engagement of stakeholders (Chapter 3). To assess the selected services, indicators and measurement methods will be identified for each (Chapter 4). The assessment of ES is accomplished by an evaluation of the economic value of ES (as described in Chapter 5). Figure 2 summarizes the process and highlights the position of the identification of ES in it.

1 http://www.interreg-danube.eu/approved-projects/eco-karst

Skills required to complete

Identification and prioritization of ES do not require any special skills, although previous experience in ES assessment is an asset. Having some background knowledge about the landscape of the assessed area is necessary, including its main ecosystems, land use types and stakeholder groups. For the stakeholder interviews and the preference assessment survey, it is also preferable for the user to have an already established social network in the area and good moderator skills. However, this is not mandatory.

Figure 1: the situation of ES identification within the schematic structure of the ES assessment

Scientific background

A couple of systems have been created to classify ES, most of them distinguishing between the three main classes: provisioning, regulating and cultural services.

- Provisioning services are material products provided by the ecosystems, like food, grains, fruit, fuel, fibre (timber, wool), herbs, natural medicine, ornamental materials (flowers, clams).
- Regulating services are ecosystem processes providing stable and safe living conditions, like air quality regulation, climate regulation, water purification, erosion control, pest control, pollination, mitigation of natural disasters and diseases.
- Cultural services are non-material benefits provided by ecosystems, like spiritual enrichment, cognitive development, inspiration, relaxation, social connections, cultural heritage, aesthetic experience and ecotourism.

These are often called final services, referring to their direct utilization or enjoyment by people. All three classes of services are indispensable for the healthy functioning of society and the economy, including local communities. As a fourth category, some classification systems (such as MA 2005, TEEB 2010) distinguish supporting services, referring to the ecological structures, functions and processes which are preconditions for the supply of final ecosystem services. Following the ES cascade framework (Potschin and Haines-Young 2011, see also at Chapter 4), however, we consider these as components of ecosystem condition (EC). Due to its high importance, ecosystem condition is also included in our assessment (see Chapter 4). In ECO KARST we used the Common International Classification for Ecosystem Services (CICES, v5.1[2], see Haines-Young and Potschin (2018)), linking each of the ES categories to the original CICES classes.

2 www.cices.eu

Exploring locally relevant ES

Instead of using an existing ES classification system as a 'top-down' starting point, in this guide we recommend the 'bottom-up' approach as a first step for the identification of locally relevant ES, based on published data and interviews. The so compiled own ES list will best reflect the specific characteristics of the area. To be also consistent with the scientific literature, however, as a next step, we recommend reviewing and re-structuring the list and linking it to established classification systems as reference.

Data needs

- existing ES assessments, landscape studies
- main geographic features, land use types and climate (e.g., National Statistical Institute database)
- local development strategy
- protected area management plan
- stakeholder database (a result of Stakeholder Identification and Involvement, see Chapter 3)

Workflow

1. Conduct desktop survey about the dominant natural characteristics and land use of the area: collect and review published data (publications, statistics, plans, strategies)

2. Carry out semi-structured interviews (see more about the method at Babbie 2013) with local experts, asking questions about:

- **2.1.** local natural values and ecosystem services
- **2.2.** past and current changes in the natural environment
- **2.3.** existing or expected environmental problems
- **2.4.** planned and anticipated development in the area
- **2.5.** determinant sectors and potential conflicts

3. Compile an initial ES list based on the results of 1. and 2.

4. Review this list to eliminate:

- **4.1.** redundancies (e.g., the same ES with different names)
- **4.2.** cases of double counting
- **4.3.** products that are beyond the production boundary

5. Match the list to an existing ES classification system, linking own ES to the published categories. It is possible that in some cases the overlapping between the two will be not 100%, in this case, refer to more than one item in the classification system (see example)

Challenges

Care should be taken to keep conceptual clarity during ES identification and to avoid the selection of items which are not ES in the strict sense. The first thing to consider is the imaginary 'production boundary' between the ecological and social systems. Ecosystem processes that reach this boundary and contribute to social benefits should be considered as (final) ecosystem services (Potschin et al. 2018). All goods and products that are further processed from that are part of the social system and are not linked directly to the natural system anymore, should not be considered ES. For example, wild fruits are direct ES, but different jams or brandies produced from them and sold in local markets are (conceptually) not, even though they can be used as indicators for this service at the fourth level of the ES cascade (see Figure 3 of Chapter 4), i.e. for the economic valuation of benefits provided by wild fruit. The position of the boundary is often context dependent and should be set clearly and consistently to avoid double counting of the same services.
Double counting occurs when two aspects of the same services are accounted and added, even though one is a precondition (and used) for creating the other. For example, when the price of hay and the price of milk are added up for the economic valuation of a grassland's service to sustain cattle, a false (too high) overall value is calculated.
A third challenge pertains to the service flows provided by the abiotic components of nature, like rocks or caves. Traditionally ES only included services generated by living processes, but recently the concept has also been expanded to these abiotic, or "environmental services". A decision to include them or not is taken for each assessment. However, once the decision is made, it has to be used consistently.

Quality check

The product of the exercise is an ES list tailored to the local situation, including natural assets as well as stakeholders' preferences and plans. In this regard, quality check means whether the ES list is comprehensive and actually reflects the reality of the assessed area. Local experts can best check this - either the interviewees themselves or others. Once the initial ES list is ready, experts can also give suggestions for the method and criteria of prioritization (see more at Selecting local priorities).

Examples

In ECO KARST, a common list of ES was created for ES prioritization and selection in the seven pilot areas. Desktop analysis and semi-structured interviews with local experts were done in all seven areas. Table 1 shows the interview questions; Tables 2-4 show the result after matching the initial list to the CICES classification system for provisioning, regulating and cultural services, respectively. Note that several ES can be referred to more than one CICES class.

*Conflicts may arise out of different land-use preferences, business activities having negative impacts on other stakeholders or because some local people do not want to accept some policy decision.

1	What is this area suitable for? What does this area offer to people?
2	What do you consider valuable/worthless in the natural environment of the area?
3	What kind of natural changes have you observed recently?
4	Who are the most influential in the landscape? And vice versa: who is affected most when the landscape changes?
5	What landscapes changes would make this area even more pleasant for people living here?
6	What are the most important planning or development projects in the area which will be implemented in the coming years?
7	Are there important conflicts in the area? *
8	Is there any other topic, which is important for many of the local stakeholders? Why is it important for them?
9	What are the most important environmental issues (current or expected) in the region? What is the stakeholders' perception of these problems?
10	What are the most important economic sectors operating in the area? (in terms of jobs, economic impacts or ecosystem impacts) Do you foresee any important change in this respect? Are you aware of any major investment or development in the area?

Table 1: interview questions in ECO KARST

Label	ES name	Definition	CICES 5.1 classes
Wild game	Wild game and their outputs for nutrition or materials	Sustainable long-term potential of the ecosystem to supply wild game and so contribute nutrition or materials to humans.	1161, 1162
Wild fish	Wild fish and their outputs for nutrition or materials	Sustainable long-term potential of the ecosystem to supply wild fish and so contribute nutrition or materials to humans.	1161, 1162
Cultivated fish	Cultivated fish for nutrition or materials	Sustainable long-term potential of the ecosystem to enable fish cultivation by providing nutrients and appropriate habitat in in-situ aquaculture. Intensive production principally relying on imported feed should not be considered here.	1141
Honey	Provision of nectar and pollen for honeybees (honey)	Sustainable long-term potential of the habitat to supply nectar and pollen for honeybees and so contribute to honey production.	1131, 1132
Hay	Natural forage and fodder (hay)	Sustainable long-term potential forage supply provided by the ecosystems through mowing or grazing. Cultivated or marketed roughage and grain feed are not included, as the amount of additional, anthropogenic input is dominant, while grazing on fallow land and stubble as well as plants spontaneously occurring on waysides and banks are included in this service.	1131, 1132
Agricultural crops	Cultivated terrestrial plants grown for nutritional purposes	Sustainable long-term potential of the ecosystem to the growth of cultivated, land-based crops and fruits grown by humans for food or harvested and used as raw material for the production of food.	1111
Wild plants and berries	Medicinal herbs, mushrooms and forest fruits used for nutrition	Sustainable long-term potential of the ecosystem to supply mushrooms, fruits, berries and medicinal herbs provided spontaneously by the ecosystem. Cultivated plants and mushrooms are not included.	1151
Timber and firewood	Wild wooded plants used for materials and energy	Sustainable long-term potential of the ecosystem to provide timber (material) and firewood (energy) to humans.	1152, 1153

Table 2: ECO KARST common list of ES for the 7 pilot areas, with reference to CICES 5.1 - provisioning services

Label	ES name	Definition	CICES 5.1 classes
Carbon sequestration	Regulation of atmospheric composition by carbon sequestration	Global climate regulation by reduction of greenhouse gas concentrations through carbon sequestration by the living biomass and soil. Carbon storage is not included.	2261
Erosion prevention	Control of erosion rates	Prevention risk of soil loss by stabilisation and control of mass flow due to the presence of natural soil cover.	2211
Water quality regulation and pollutant removal	Regulation and maintenance of chemical condition of water	Regulation and maintenance of good chemical condition of freshwaters by living processes, as well as transformation, fixing and storage of organic or inorganic pollutants that enable human consumption and use of water.	2251, 2111, 2112

Table 3: ECO KARST common list of ES for the 7 pilot areas, with reference to CICES 5.1 - regulating services

Label	ES name	Definition	CICES 5.1 classes
Touristic attractiveness of nature	Physical and experiential interactions with nature	Contribution of ecosystems through their attractiveness to tourism, recreation, outdoor sports, observation and enjoyment of aesthetic beauty of the landscape. Attractiveness and use of abiotic features - like caves, rocks, and other karst geomorphological features - also belongs here.	3111, 3112, 3124, 6111
Education and training	Nature-based education and training	Capacity/use of ecosystems (including abiotic features) as subject matter for in-situ teaching or skill development.	3122, 6121

Table 4: ECO KARST common list of ES for the 7 pilot areas, with reference to CICES 5.1 - cultural services

Selecting research priorities

Once a comprehensive list of locally relevant services is created, the next decision to be taken is which services from the list should be actually mapped. Ideally, it would be all of them. In reality, time, expertise, capacities, data availability and money constraints restrict the number of services that can be modelled, measured and mapped in detail. So the initial list of ES has to be prioritized to enable a comparable, comprehensive and documented selection which takes several aspects into consideration.

ES prioritization method 1: expert-based selection against a set of criteria

Data needs

- initial list of locally relevant ES
- stakeholder database for the selection of experts (a result of Stakeholder Identification and Involvement, see Chapter 3)

Workflow

0. select the experts to work with

1. assess the list of ecosystem services one by one against the below selection criteria, estimating whether a certain ES is relevant or not (scoring 1 or 0) in the pilot area considering each criterion

- **1.1.** Ecosystem types concerned
  - **1.1.1.** can the ES be linked to locally specific ecosystems?
  - **1.1.2.** can the ES be linked to an ecosystem type of large land surface within the pilot area?
  - **1.1.3.** can the ES be linked to an ecosystem type of small land surface, but high conservation value?
- **1.2.** Benefits for local people
  - **1.2.1.** can the ES provide economic benefit for the local economy (in terms of jobs or GDP)?
  - **1.2.2.** can the ES provide non-marketed livelihood for local people (e.g. grazing animals for self-sustaining, collecting mushrooms)?
  - **1.2.3.** does the ES have a high capacity for benefit which is still underutilized, predicting a potential for PBB development?
- **1.3.** Local relevance
  - **1.3.1.** is the ES important in the perception of local people (e.g. cultural heritage, local customs and events, local identity)?
  - **1.3.2.** is the ES part of an important local issue in some way, e.g. subject of development plan or land use conflict?
- **1.4.** Relation to other ES
  - **1.4.1.** is the ES inherently bundled with one or more other ES (thus its assessment can indirectly provide information for those too)?
  - **1.4.2.** is the ES in trade-off with one or more other ES (thus its assessment can indirectly provide information for those too)?

2. create a priority list of ES by adding up the scores of each ES to an aggregated score of 'relevance', rank ES in descending order of their overall scores

Challenges

The set of criteria described here is generally suitable for the assessment of ES on protected areas at the regional scale. However, the motivation of a concrete ES assessment and intended use of its results in a concrete area and socio-economic setting might require the revising of the general criteria, to have these motivations and intentions better reflected already at the ES prioritization phase. If this is the case, experts can suggest the weighting of some criteria or adding new ones to the list.

When assessing ES against criteria, the involvement of experts can bring bias towards the land use type / economic sector they represent. To ensure a balanced decision, we recommend to set up a small group of 2-4 people representing the most dominant land use types of the area. Experts should be asked to discuss conflicting opinions and make consensual decisions.

Data and methodological limitations: even if an ES is generally considered relevant, it cannot be included in the assessment if there are no data sources or methods available.

Quality check

For a comprehensive regional assessment, it is recommended to set up a permanent advisory board at the beginning of the process. This board, consisting of local experts and stakeholders, can play a supervisory role and perform quality checks at every major step of the process, including the selection and prioritization of ES.

In case a service is considered particularly highlighted or vulnerable (e.g. subject of an ongoing development or land use change), it can be selected for mapping despite not being ranked very high. Such decision has to be carefully made by the permanent advisory group.

Examples

This method was used in ECO KARST for the prioritization of ES. As a basic rule, the most relevant (highest scored) services were selected for mapping in all of the 7 pilot areas. However, this rule was modified in some cases by the following aspects:

- All three ES categories (provisioning, regulating and cultural services) have to be represented in the final selection.
- Aggregation of services is possible if two or more services can be assessed and mapped by the same indicator and method. This happened in the case of touristic attractiveness and nature-based education in Bijambare.
- Splitting of services is possible if the service consists of components that cannot be assessed and mapped by the same indicator and method. This happened in the case of herbs, mushrooms and wild berries in Apuseni.
- In case there are serious data constraints concerning a highly ranked service which would make its assessment and mapping

impossible (e.g. new field inventories or data purchase beyond the project budget would be necessary), the concerned ES can be dropped from the list. This happened in the case of erosion prevention in Bijambare.

The prioritization table of Bijambare is shown in Table 5.

As a result of the prioritization, lists of services assessed and mapped by the 7 pilot areas in ECO KARST were not identical but reflected the biophysical and sociological differences from pilot to pilot.

		Selection criteria										Sum of scores
		01.jan			01.feb			01.mar		01.apr		
		01.01.2001	01.01.2002	01.01.2003	01.02.2001	01.02.2002	01.02.2003	01.03.2001	01.03.2002	01.04.2001	01.04.2002	
Prov. ES	wild game	0	1	0	0	1	1	0	0	1	1	5
	wild fish	0	0	0	0	0	0	0	0	0	0	0
	cultivated fish	0	0	0	0	0	0	0	0	0	0	0
	honey	0	1	0	1	1	1	1	1	1	0	7
	hay, fodder / output of grazed livestock	0	1	1	1	1	1	1	1	1	1	9
	agricultural crop	0	1	0	1	1	1	1	0	1	1	7
	medicinal herbs, mushrooms and berries	1	1	1	1	1	1	1	1	1	1	10
	timber and firewood	0	1	0	1	1	1	1	1	1	1	8
Cult. ES	**touristic attractiveness of nature**	1	1	1	1	1	1	1	1	1	0	9
	education and training	1	1	1	1	1	1	1	0	1	0	8
Reg. ES	carbon sequestration and storage	1	1	1	0	0	0	0	0	1	1	5
	erosion prevention	1	1	1	0	1	0	1	1	1	1	8
	water quality protection (pollutant removal, drinking water quality)	1	1	1	0	1	0	1	1	1	1	8

Table 5. Result of prioritization in Bijambare. Criteria codes refer to numbers as described in Workflow. ES selected for mapping are shown in bold. Note that the ES education and training were merged in the touristic attractiveness of nature, and the ES erosion prevention was dropped due to data constraints.

ES prioritization method 2: preference assessment survey

In order to make the ES assessment locally as relevant as possible, the initial ES list can be ranked with the involvement of a broad range of local people.
A preference assessment survey helps understand local inhabitants' perceptions of ES and prioritize them according to how they perceive the importance of ES in the local context. For a more detailed description of the methodology see Kelemen et al. (2014) and García-Llorente et al. (2012).

Challenges

- initial list of locally relevant ES
- ES photographs taken in the research area

Workflow

1. create a photo-panel:
  - **1.1.** define the preliminary list of ES in lay language
  - **1.2.** illustrate all ES by photographs taken in the research area

2. using the photo-panel as a visual aid, ask respondents to:
  - **2.1.** select the five most important ES provided by the research area
  - **2.2.** rank the 5 selected ES according to their importance

3. collect general demographic and socio-economic data (gender, age, school degree, involvement in sectors relevant for the provision of ES)

4. create a priority list of ES on the basis of respondents' votes with 2 possible methods:
  - **4.1.** simple arithmetic summation of individual ES votes (not taking into account the respondents' ES ranks)
  - **4.2.** summation of ES votes weighted by their 1-5 ranks (multiplication factor = 6-rank)

5. (optionally) analyse which individual characteristics influenced respondents' preferences and whether there were any common patterns of preferences across different groups of respondents

Challenges

If the sample of respondents is not representative of the local population, there is a possibility of biased results due to the overrepresentation of certain ES favoured by overrepresented demographic groups or stakeholders (e.g. respondents involved in agriculture) in the sample. Data and methodological limitations: even if an ES is generally considered relevant, it cannot be included in the assessment if there are no data sources or methods available.

Quality check

This method requires a considerable amount of time and capacities. It is suggested that data collectors should undergo training before the field work to ensure uniform method and to avoid potential personal biases.
For a comprehensive regional assessment, it is recommended to set up a permanent advisory board at the beginning of the process. This board, consisting of local experts and stakeholders, can play a supervisory role and run quality checks at every major step of the process, including the selection and prioritization of ES.

Examples

Due to limited time and capacity, in ECO KARST we did not use this method. However, an example of the use of preference assessment in a regional ES assessment in Romania is described by Czúcz et al. (2018) and in detail by Kelemen et al. (2017).

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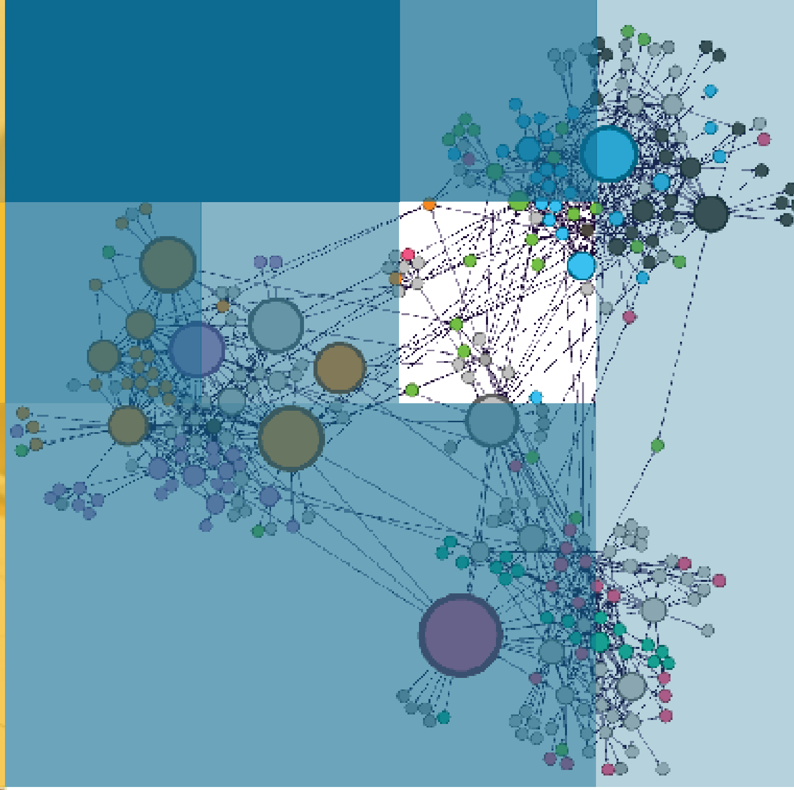

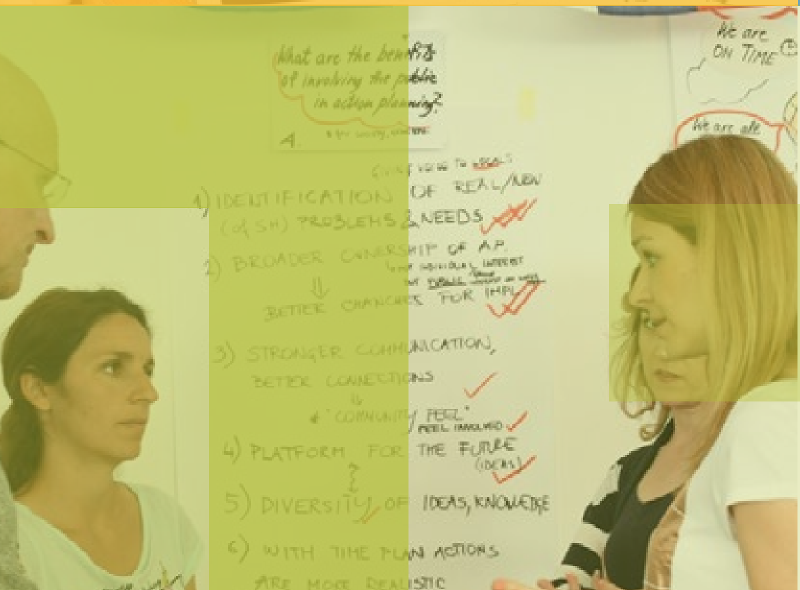

Identification of relevant stakeholders

Béla Kuslits, Barbara Sólyom

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Introduction

In any project dealing with the management of natural resources, stakeholders have an important role. Landscape management – by its nature – cannot be centralized effectively as it is carried out through many different activities: agriculture, forestry, urban development, etc. and it is also shaped by the responses of the ecosystem. Stakeholders are usually not involved in scientific research, still their knowledge is relevant and highly valuable as it is based on a unique day-to-day experience. Integration of different knowledge systems is more and more widespread and is an efficient approach to natural resource management especially in uncertain times.

Stakeholder involvement can be useful both for scientific purposes and decision making. It makes the process more democratic and more efficient as well. It is more democratic as it builds on a more inclusive understanding of knowledge and takes into account the interpretations and interests of those who are living in direct connection with nature. It is also more efficient as involving land-users enables decision makers to tap into a broad range of knowledge and also helps to avoid decisions that would be opposed or obstructed by excluded stakeholders. Thus, stakeholder involvement is a way to integrate conservation and economic needs of the local people, thus it is especially important when ecosystem services management is the goal of a project.

To be effective, stakeholder involvement should be inclusive, build on a neutral communication and should treat involved stakeholders as equals.

1. Inclusiveness means that no stakeholder, person, group or institution should be left out that is in connection with the land – no matter what political or economic role they have. Selection processes favouring "important" local players (identified by the assessment team) should be used with precautions and only if no other way is possible. In this case selection criteria should be explicit and non-discriminatory. Established structures and communication channels should not be taken for granted as an unbiased representation of the local people.
2. Neutral communication means that the manager who builds on the results of the stakeholder involvement should let all voices be heard, without supressing those who have different views on an issue. Natural resource management often invokes stark debates about questions of land use and habitat management – here the goal of communication is to find interpretations that reflect the interest of as many stakeholders as possible including future generations. Even if the facilitator is employed by one of the stakeholders or authority, the opinion of this organization should not be overrepresented.
3. Treating stakeholders as equals means that players with established access to decision making should not be favoured during discussions and debates. Many times, stakeholders who are not directly involved in landscape management have higher stakes in decisions – their views need to be considered.

Goal of the document

The goal of this document is to provide methodologies for identifying and selecting stakeholders for participatory work in natural resource management. This process consists of three major steps: (1) identifying groups of stakeholders by examining social-ecological interactions, (2) mapping power relations of stakeholder groups in order to facilitate a more inclusive approach to these groups, (3) social network analysis to understand the structure of information processing within the local community and to determine which special roles are present and who are influential figures among the locals.

Place in the assessment process

Identification of relevant stakeholders is the third document in the series of guidance documents describing a participatory MAES (Mapping and Assessment of Ecosystem Services) process. As volume 1, 2 and 4 are mainly focusing on the technicalities of ecosystem services (ES) assessment, this volume 3 focuses on the sociological background of the ES use and management. Since our methodology is participatory both in assessment and in decision making, it is crucial to step beyond naïve interpretations of stakeholder involvement and apply a systematic methodology to find those who are affected by the results of the process. Stakeholders are not just the decision makers and the influential, but all people who interact with the ecosystem in question – all should be represented, or at least given a chance to be involved.

Skills required to complete

A **background in social sciences** and/or experience with empirical methods of social sciences is an advantage, however it is possible to work without these qualifications. These skills are especially important when power relations are mapped and while administering the questionnaire. These are steps where sensitive use of language and attention to detail can greatly improve the quality of the results.

High level of **computer literacy** is mandatory but no special training (such as programming) is required. While more advanced tools will be mentioned, social network analysis will be primarily carried out with an open source software (Gephi) that has an acceptable user friendliness. Apart from Gephi, a spreadsheet editor is a necessary tool for data pre-processing.

Scientific background

Our methodology of stakeholder involvement applies the three-step approach described by Reed and his colleagues: (1) define relevant social and ecological phenomena to consider, (2) identify individuals and organizations who can be affected by the decisions to be taken, (3) prioritise individuals and groups for the process of involvement (Reed et al. 2009). Stringer and her colleagues summarize that stakeholder involvement, broadly speaking, has two main advantages: it is a better way to capture information about a habitat to be managed, and also, this is a more democratic way to do so. They remind that participatory processes often are appearing to promote social learning and co-management, yet in practice decision making remains autocratic. One of the reasons behind this is usually the lack of interest on the side of stakeholders who are more distant from the decision-makers. An effective stakeholder involvement therefore needs to actively encourage their participation and give time and opportunity to build trust among stakeholders. The success of this process depends on feedback loops between participants and the outcomes of the common process: did these actually achieve what has been promised? Stakeholder involvement can only be successful if the organizers are dedicated from the starting point that they want to involve people who are beyond the group of already loud and visible partners – which means that time and effort is given to build relations and adapt to new expectations (Stringer et al. 2006). Successful participatory processes usually build on a framework that enables the integration of scientific and local knowledges; focuses on empowerment, equity, trust and learning which also means that the powerful actors are kept in balance; stakeholder involvement should be considered early; an analysis of stakeholders is necessary; clear objectives and methods that fit these objectives have to be selected; highly skilled facilitation has to be applied and finally participation needs an institutional frame (Reed 2008).

Ecosystem Services (ES) management is an especially complicated issue from the stakeholder involvement point of view, as many ESs are provided by the landscape, these services are often in a trade-off relationship (Turkelboom et al. 2016; Raudsepp-Hearne, Peterson, and Bennett 2010), while also many groups of stakeholders are connected to them with different views, interests and power. Without seriously considering power relations of stakeholders, the involvement process cannot lead to substantial results as the status quo in power relations and informal influence holds the keys to decision making. ES studies are usually induced by the realization of some unsustainable processes, desire of change in landscape management or as a response to a specific local problem. Ecological and social processes are deeply entangled in these kinds of decisions, thus stakeholders' (1) decision making power and (2) reliance on specific services needs to be addressed in an explicit manner, and these relations are to be considered when plans and decisions are made (Felipe-Lucia et al. 2015). Social Network Analysis (SNA) is a tool that is widely used to do enhance analysis for natural resource management projects (Bodin and Prell 2011). It also has been applied for planning stakeholder involvement processes where key players have to be found in order to have a fair representation of all groups regardless of their power or existing relations with the resource managers (Prell, Reed, and Hubacek 2011). SNA is a tool to uncover key players in a large and complex group of stakeholders, it is able to describe structural characteristics such as informal decision making and also contributes to the understanding of the processes that shape human interactions. In this methodology description, we will offer methods to do all of these in order to enhance the efficiency of natural resource management. SNA is a computer assisted method of sociology. A good description of the methods is offered by

Borgatti and his co-authors (Borgatti, Everett, and Johnson 2013). We will use the open-source software Gephi (Bastian, Heymann, and Jacomy 2009) and Borgatti and his colleagues' software to do the technical tasks of the network analysis (Borgatti, Everett, and Freeman 2002). Additionally, for more advanced users, iGraph (an R and Python library) is a recommended tool (Csardi and Nepusz 2006).

Compiling Stakeholder Database

The first step is to compile a database of all stakeholders who are managers or beneficiaries of ESs in the protected area. Access to the following databases may be limited. Compiling a stakeholder database is possible without some of these, but a broad overview of the stakeholders and efficient communication with them is necessary in order to do a successful analysis.

Data sources

- Land-use contracts or GIS-based collection of land managers/owners
- Management plans
- Databases on tourism
- Data on infrastructure elements within the area
- Permissions issued for activities and events in the area
- Event calendar (for local events, events that are relevant to the analysis)
- Local news sources (media)
- Municipalities, associations, chambers of commerce
- Farmers' market and other local distribution platforms
- Online fora, relevant Facebook groups, etc.
- Official partnerships, committee memberships, administrative relationships
- Informal partnerships

Workflow

Stakeholders are persons and organizations that rely on Ecosystem Services of the area in question or have an effect on the condition or use of Ecosystem Services.

The questions below represent various approaches to find stakeholders. Managers of protected areas might know many of them from existing partnerships or past projects, still it is important to review existing stakeholder databases to ensure the highest level of inclusivity.

Use the questions below to identify stakeholders and groups. Most of these can be answered by using a land-use map, looking at rental-contracts or other structured data detailing official connections between the park management and stakeholders. In other cases, existing stakeholder databases or online research may be sufficient. In any case, it is necessary to document the data sources applied while building the database.

Wherever it is possible, list individuals instead of organizations – for instance, local farmers should not be covered by just an association they may be members of, even if representatives of that organization might have a special role. In the case of administrative institutions,

where the legal mandate of the organization is more important than the persons involved, the institution should be mentioned in the data table referring to a contact person who can participate in the process.
1. What landscape features indicate social-ecological interactions? Land-use types indicate economic activities in many cases (forestry, agriculture, tourism, industry) - who are officially responsible for land-management at each spot? (owner, tenant, manager of an institution, company executive) Ideally, each polygon on your ecosystem map should belong to a stakeholder.

2. What infrastructure elements are crossing the area in question? (roads, railway lines, pipelines, wells, etc.) Who is using the infrastructure? What organisations are managing these facilities? Are there infrastructure elements that are directly building on ecosystem features (such as drinking water provision)?

3. What are the most frequent use-cases of the area during each season throughout the year? What institutionalised or traditional activities are most common? What groups are the most frequent or most numerous users of the landscape during each season? Think of events or activities organised by NGOs, government bodies or businesses but also individual activities depending on seasonality such as harvesting fruit in fall, winter sports, etc.

4. Identify enterprises in the region. Which companies create the most jobs? Who is investing in the local economy? What sectors, professional profiles are the most important in the area? List small, medium and large companies.

5. Individual land-use is important, however if there is no representative organisation, individuals cannot be tracked easily. In some cases, marketplaces, online fora, Facebook groups provide effective communication channels towards individual landscape users. Map these communication platforms and community spaces with the help of already existing partners, try to identify relevant representatives (one or more) for each of them.

6. Which stakeholders are interested or involved in the landscape management in a more systematic way? "Systematic" means that these stakeholders see the landscape as a whole and propose management practices taking into account a wider context. This does not require to be legally entitled to implement these views. Usually, there is the main stakeholder, such as a Forest Service, or National Park and a few other players such as conservation NGOs, infrastructure organisations (e.g. watershed management), local municipalities, etc.

7. Are there organizations, apart from the managers of the protected area, that are concerned about the region? Conservation NGOs (local or global), local development organizations, schools, research institutions, and groups or any organization without formal connection to the area management, who are involved in some activity or are concerned by the status of the protected area.

Depending on what form of data collection is planned for later phases, email addresses or physical addresses of the stakeholders should be collected., Email is best when an online survey is planned, and physical address is good when a paper-based survey is implemented.

Challenges

The greatest challenge in this part is that organizations often have similar databases and thus are reluctant to review them or broaden their scope as it seems "unnecessary" since the "most important" stakeholders are already in there. Our view would challenge these claims: no stakeholder is more "important" than the others, maybe some are more "powerful". Our goal is to find those who have less voice in the usual local processes and are less influential than others. For these reasons, it is advisable to create the broadest possible database. This will also contribute to a higher quality of later results, giving more detailed information and having a better chance to reveal previously unknown communication patterns or influential actors.

Nr	Name	Person / Organization	Contact	Description
1	Julia Smith	Person	email	City Council member, farmer
2	WWF	Organization	email	NGO
3	Farmers' Association	Organization	email	70% of farmers are members
4	Christopher Brown	Person	phone	retired, tour guide, hunter

Table 1: an example of the stakeholders' database. All rows represent people or organizations with their contact information and a short description. The information in the table is just an example.

Quality check

- All of the questions about social-ecological interactions have been answered and records are entered into the database
- All rows of the data table have names of persons or organizations and contact information and as little missing data as possible
- Typos are corrected, duplicates removed – see also Section "Data cleaning" on this topic important aspects of the natural-resource governance system. The two main attributes of the listed stakeholders will be (1) their ability to manage ESs and (2) their dependence on them.

Stakeholder groups

In this section, stakeholders will be sorted into groups that will support the implementation of the next section and also inform about important aspects of the natural-resource governance system. The two main attributes of the listed stakeholders will be (1) their ability to manage ESs and (2) their dependence on them.

Data needs

No new data is necessary, groups are created using the database described in the last section. A group of people who know the local stakeholders well will organize the previously compiled data into the framework described below.

Workflow

Sorting stakeholders into this framework (figure 1) cannot be completely formalized, it is best implemented by a group of people who have a good overview of the area and the stakeholders as well. Park managers, local NGOs, informal community leaders usually have a personal network broad enough to do this. Ideally, the result should be shared with a wider group of stakeholders at a community meeting or participatory workshop, depending on what is expected. Local stakeholders could then endorse or improve the categories and their placement in the framework. There are probably multiple ways to categorize stakeholders. For our purposes (assisting data collection for SNA) 6-7 groups would be best. Individual categories should reflect the different legal status of stakeholders, their different decision-making powers and also different economic or social influences. Depending on the governance system, there is either a national or a local central player who coordinates the management various other stakeholders have more or less power to make decisions in particular questions. In this framework decision making is not just policy making: operating a farm, harvesting a resource or introducing a new service constitutes decision making even if much less consequential than a strategic plan or high-level regulation. Decision making focuses on specific social-ecological interactions in most cases, thus besides considering the ability to shape decisions, it is possible to identify which ESs belong to which group and depending on their activities, and business model, the level of dependence can also be estimated. Figure 1 is an example of this structure. In a centralized park management structure, state administration is in the top left corner with little dependence on ES but high power of decision making. NGOs have a very limited role on this chart as limited influence and ES use makes them marginal players. Recreation is a key sector. Its representatives both influence and use ESs heavily. Obviously, in other parks completely different arrangements may be possible, depending on the legal framework and local traditions. Needless to say, categories need to cover all stakeholders who have been collected in the database. In the next phase, these groups will be used in the SNA survey. Therefore, it is a good idea to use groups who are easily identifiable and clear for most people.

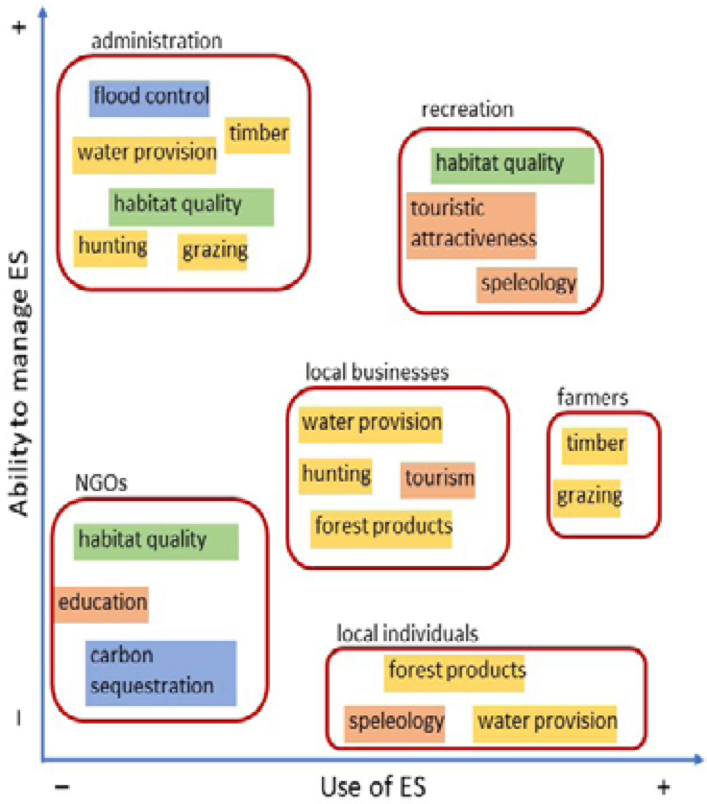


Fig. 1: A visual representation of the stakeholder groups framework. Groups are located by their ability to manage ESs and their dependence on them. Inside the boxes the relevant ESs are listed, colours represent ES categories (provisioning, regulating, cultural)

Challenges

- Sometimes certain institutions do not belong to a group of similar stakeholders as they are unique in some sense – in these cases, they can form a group on their own. This is especially necessary if a stakeholder is privately managing a large area of land[1] .
- While it is not complicated to rank stakeholders by their legal entitlement to decision making, their informal power is usually much more obscure. Since influence is highly context- dependent, no general methodology exists to tackle this challenge., However, the group of people who sort stakeholders will be able most likely to describe how informal influence was taken into account.

Quality check

The result of this exercise should be validated by a wider group of local stakeholders. There are no formal requirements for the outcome.

1 A similar example is Tara National Park (Serbia) in the EcoKarst project. Here the Rača Monastery manages a large and independent area within the park. They also use various ESs that they consider appropriate and are more independent in terms of regulations compared to other stakeholders.

Examples

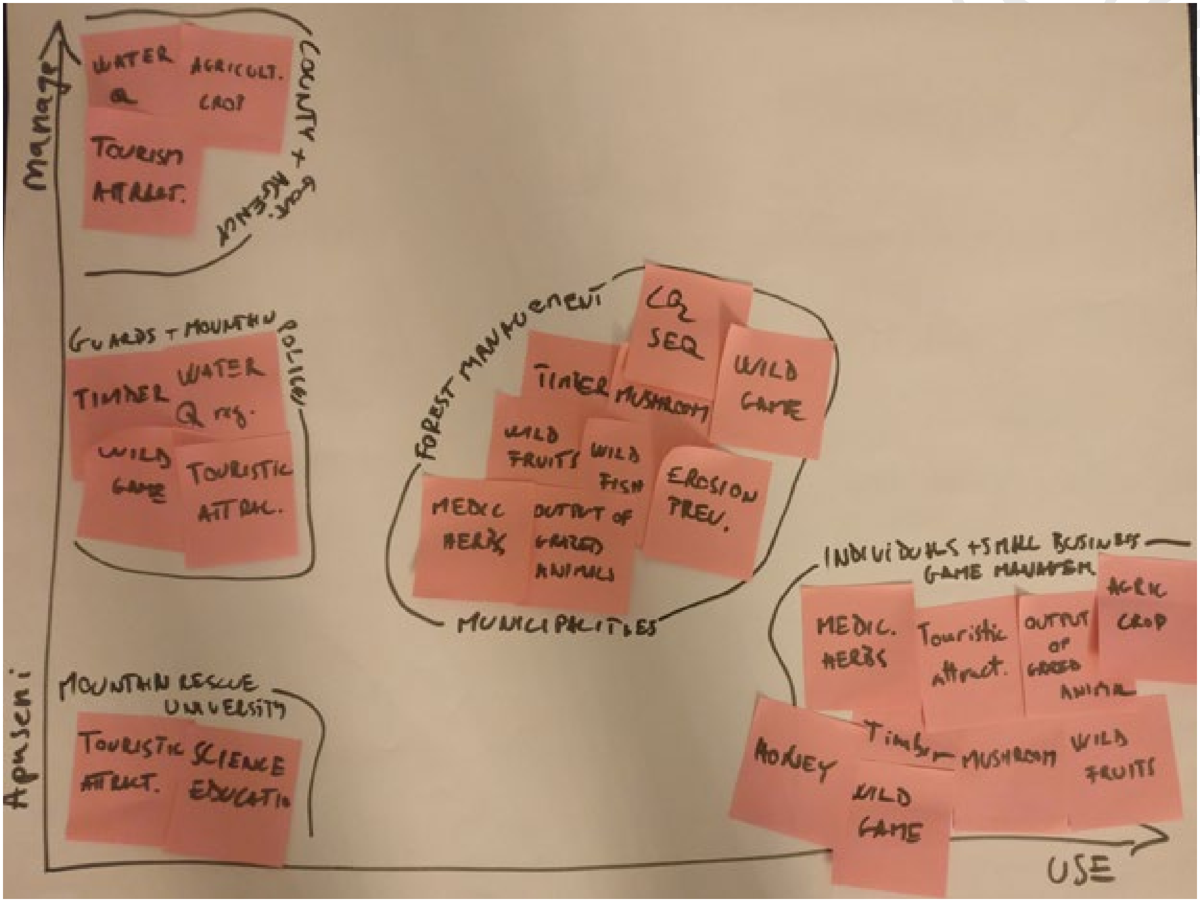
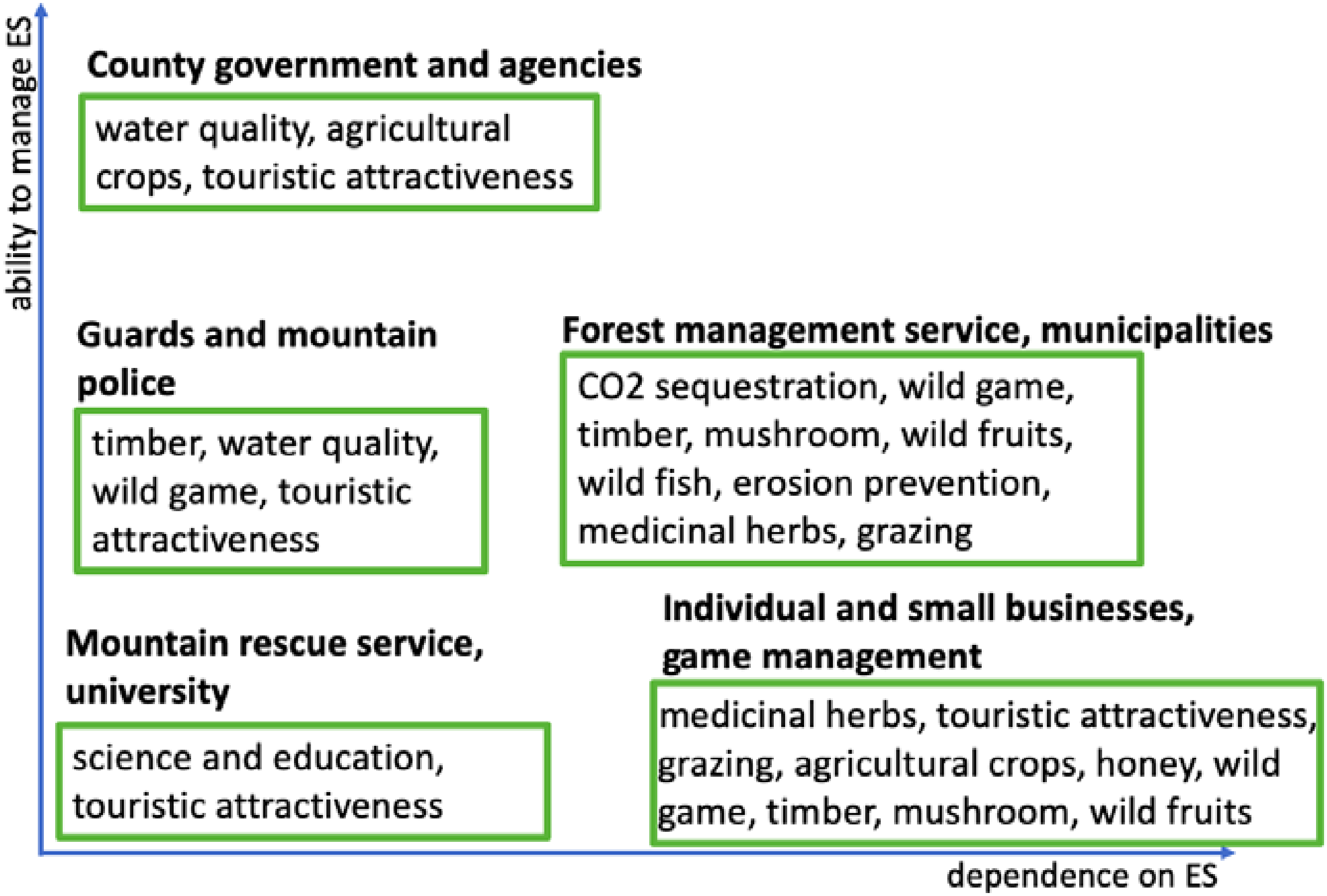


Fig. 2: stakeholder groups identified in the Apuseni National Park (Romania) in the EcoKarst project. This case was a National Park where local decision-makers have a relative independence from the national level compared to other Central-European protected areas – this can be seen that local municipalities do the forest management and many other ESs belong to them.



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Social Network Analysis

Data collection

Data format

Social networks represent an interconnected social sphere where institutions and individuals interact in some dimension. Nodesrepresent players in this network: institutions and persons in our case, in other cases nodes can have different meanings, even social and ecological elements can be connected. Edges of the network represent some type of connection between nodes. These connections have to be standard, defined relations, such as having business ties, communication, friendship, etc. The web-like interconnected structure of nodes and edges is called a network graph. Its analysis (SNA) is capable of understanding a wide variety of features that are otherwise complicated to show.

Social Network data can be collected both online and offline. The purpose of this task is to collect structured data on the network relations and attributes of the network members. The result will be two data tables an edges table and a nodes table. These two tables are the sources for building a network graph showing the relations among stakeholders.

An edges table describes the relations between the nodes of the network. It is a list containing sources and targets of relations in a directed manner which means if A mentioned B as a contact does not necessarily mean that B also mentioned A as a contact. This will be important when interpreting the results[2]. Directed relations contain different kind of information than undirected ones and are also easier to collect. The structure of an edges table is shown in table 2. The nodes table contains the same nodes that are in either column of the edges table, but it contains them only once and also stores attributes about them such as "location", "sector", or anything that seems to be useful to be collected. Later, when the network is visualized, individual nodes can be sized or coloured based on these attributes. The structure of the nodes table is shown in table 3.

Collecting data into two tables would be very inefficient so the survey and the first format of processed data will be in a third format where all information is being stored together, can be manipulated and cleaned together before separating it into edges and attributes tables. Table 4 shows the format of data collection and processing. In this format data cleaning is not very complicated.

2 To give an everyday example, directed contacts are like Twitter followers, undirected contacts are like Facebook friends. While Facebook connections are mutually accepted and all my friends have me as a friend, on Twitter I can follow others who do not follow me back.

Source	Target
John	Julia
John	Peter
Peter	Julia
Julia	Jill

Table 2: edges table example: respondents are listed in the "Source" column and their contacts in the "Target" column. Names can be repeated in both columns as a single actor can have many connections.

ID	Gender	Sector	Location
Julia	F	Researcher	town1
John	M	Farmer	town2
Peter	M	Administration	town2
Jill	F	NGO	town1

Table 3: nodes table example: the nodes from Table 2 have attributes that are described in the nodes table. Here each name appears only once.

Source	Gender	Sector	Location	Target	Gender	Sector	Location
Julia	F	Researcher	town1	John	M	Farmer	town2
Julia	F	Researcher	town1	Peter	M	Administration	town2
Peter	M	Administration	town2	John	M	Farmer	town2
John	M	Farmer	town2	Jill	F	NGO	town1

Table 4: data collection table example with the data of the edges and nodes table together. Rows are ordered by the information of the edges table (see columns "Source" and "Target") while node attributes are also shown. With right side of the table being copied under the left side and removal of the duplicates, the nodes table can be produced.

Data in the tables 2-3-4 produces the network graph on figure 3.

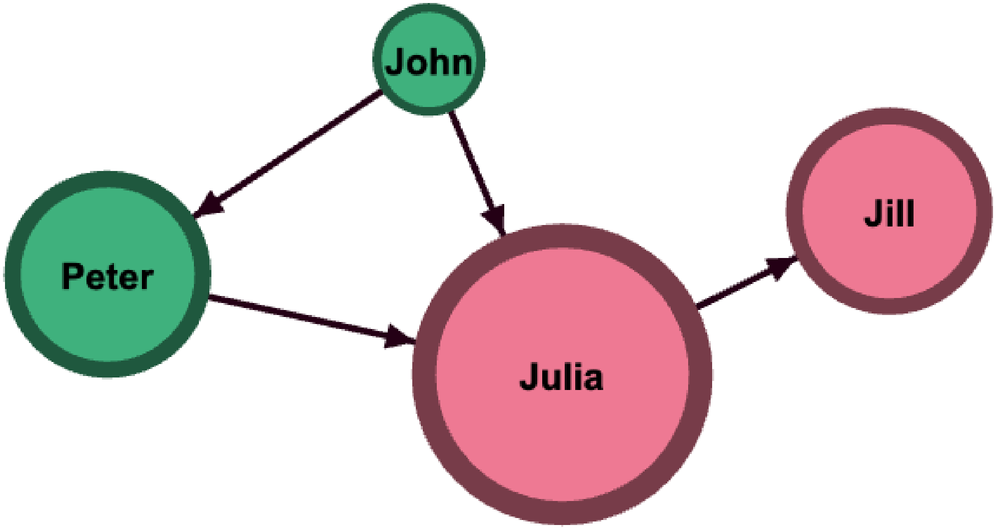

Fig. 3: example of a directed network graph. Colour represents the settlement the nodes belong to, size represents the number of incoming edges, the direction of edges is represented by the arrow-head.

Data collection

Data can be collected through a paper-based survey or an online survey. With online surveys, data processing becomes an easier task but no online service exists that is specially designed for this kind of data collection[3]. Also, despite the easiness of the online survey administration, many times paper-based surveys are more efficient tools to collect answers. If it is possible, park rangers or other personnel who meet stakeholders regularly are in a position to let people fill in surveys in large numbers. They are also able to explain the goal of it and answer questions about handling of personal data which is usually raised by respondents.

The survey first asks the attributes of the respondent, then asks the following question for all of the stakeholder groups identified in the second section: "Who do you communicate with about questions of natural resource usage from the GROUP X in connection with the Y AREA? Please list up to 5 persons or institutions." The answer sheet is similar in form to the nodes table: it has five rows, a column for the name and a few columns for the attributes. Having 6 groups leads to 6 similar questions where 5 names can be listed, thus one respondent can name 5 x 6 = 30 contacts. In practice, they usually do not fill in all the rows, which is not a problem. Having different groups in the questionnaire helps respondents to think about all stakeholders and not being influenced too much by their first ideas.

Name	attribute 1	attribute 2	attribute 3

Table 5: template for social network data collection. Name can be both person or institution. Attributes should be defined in a way that fits both categories.

Attributes can also be filled in by the respondents. Most probably, attributes given by different respondents will not be completely consistent across the table, this problem can be solved during the data cleaning process.

3 SoGoSurvey was used to collect network data in the EcoKarst project. At the time when data was being collected (spring of 2018), the survey tool only had a question format where the answer could be a table where each cell can be filled in by the respondent (matrix grid – see: https://www.sogosurvey.com/help/survey-question-types/). The tool provided a CSV file as output that did not have a very clean structure and had to be pre-processed with a python script before being opened with MS Excel. We will not discuss this in detail here but only describe the required output format considering that online survey tools are developing fast and probably in another case a different solution would be required.

Data processing and analysis

Data cleaning

The goal of data processing is to create an edges table and a nodes table that are consistent with each other. Since network graphs are drawn by computers, even the smallest typo can cause a problem, so the first and most important task is data cleaning. It is easiest to do it in the format of table 4: all names have to be in the same format. It is important to pay attention to small errors, for example, Peter is not the same as Péter for a computer while for a human reader it is easy to recognize that they are the same. Similarly, some respondents may use abbreviations, some not, thus it is important to see that WWF is the same as World Wildlife Fund. In the next step, when data cleaning is done, the edges table and the nodes table can be easily constructed. To get the edges table, it is enough to remove unnecessary columns. To get the nodes table, the two sides of the table should be copied into the same 4 column order, and duplicates have to be removed. It is likely that some rows in the nodes table will not be completely consistent, as different respondents might think differently about their contacts. In these cases, the best row has to be selected. If it is available, use the one that was provided by the player in question. If not, see what is the majority opinion, or check their website.

Draw a network graph

With Gephi, a network graph can be easily drawn. It can import Excel files that follow the format of nodes table and edges table detailed above. In Gephi there are three modes to manipulate graphs: "overview", "data laboratory" and "preview". We will use the first two.

In the "data laboratory" mode data can be imported, exported and manipulated as a table. In the "overview" mode the appearance of the graph can be changed, and some statistics can be calculated. Statistics describe the nodes individually, for example, tell how many connections they have. These attributes will automatically be added to the nodes table as a new column. The graph can be coloured, rearranged and nodes can also be resized in "overview" mode. These allow for seeing the graph as a whole, where different features are apparent. For such a basic network graph, see figure 4.

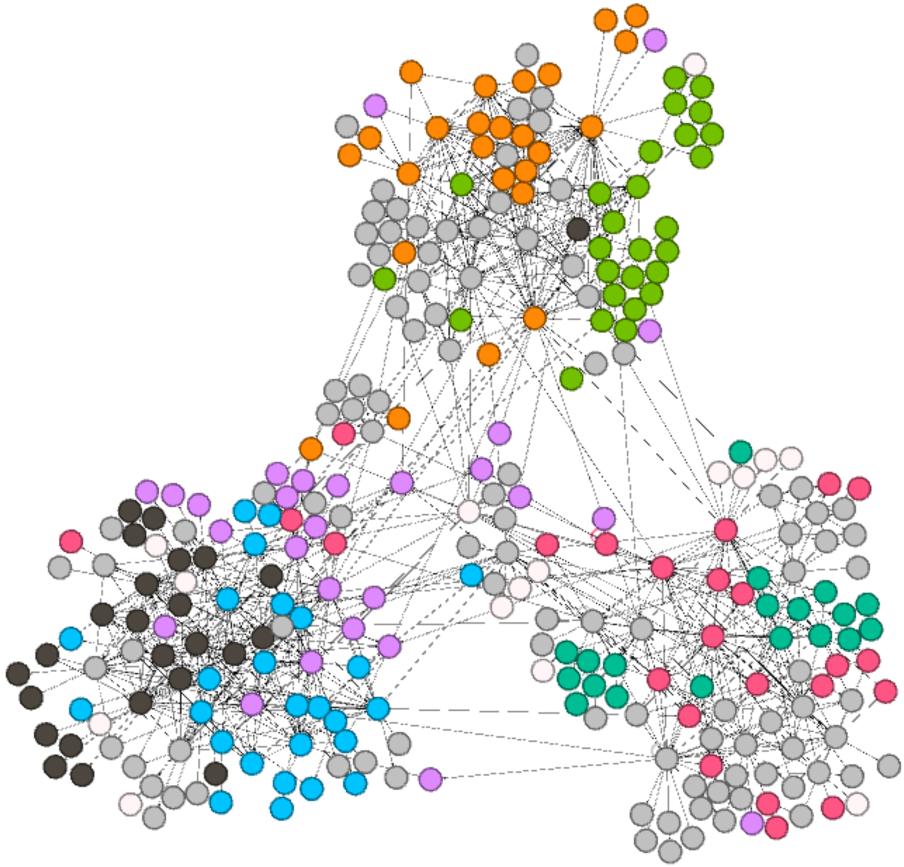

Fig. 4: Stakeholder network from the Apuseni National Park, Romania. Nodes are coloured according to the settlement they belong to (grey colour is a mixed group with many settlements that only have 1 or 2 nodes). It is apparent that players that operate close to each other belong to tightly connected subgroups within the whole network. Different settlements that belong to the same subgroup are geographically close to each other. Nodes having more connections in common are located closer on this figure thus tightly connected subgroups can be observed. There is a strong connection between location and subgroup formation in this case.

Interpretation of results

Degree, in-degree, outdegree: the number of connections a node has. Indegree describes the incoming connections, outdegree the outgoing connections, degree is the number of all undirected edges. Since not all our nodes were also respondents, out-degree can be disregarded with this methodology. In-degree, however, is very important, as a high in-degree shows trust or authority.

Betweenness centrality: describes how many times a node is on the shortest path between two other nodes in the whole graph. The higher it is, the stronger is the bridging-capability of that node – this can be capacity to solve conflicts, to unite distant viewpoints, to pass on viewpoints, information from one group to another. In figure 5 node size is determined by the betweenness centrality of the players.

Fig. 5: Stakeholder network of the Bükk National Park in Hungary. Size of the nodes represents the betweenness centrality of the nodes, colour represents the sector they belong to (brown: forest management, pink: NGO, yellow: municipalities, green: small businesses, purple: tourism)

Core/periphery: not always relevant (some networks do not have a core/periphery structure). In some networks there is a central group that has a formal or informal influence on most of the decisions – these nodes form a core group that is well connected, and all others are connected to this core more loosely. This can be calculated using UCINET[4] (see Figure 6.).

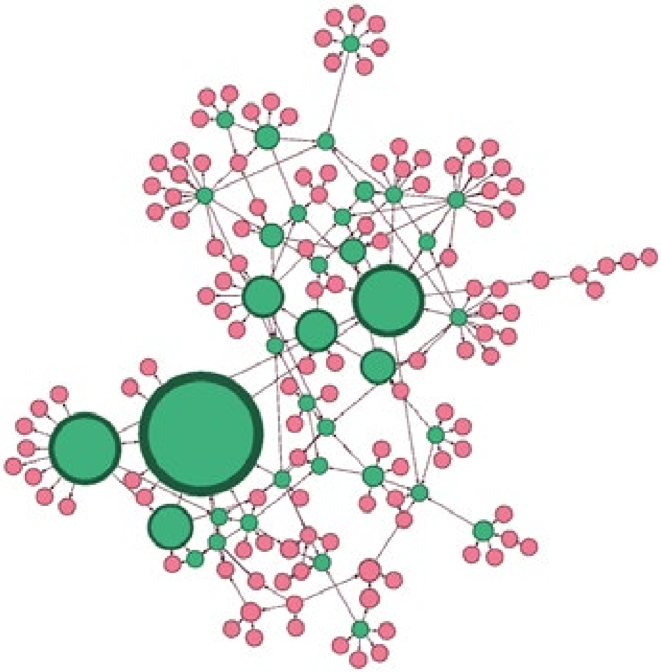

Fig. 6: Core/Periphery structure in the Zumberak Samoborsko Gorje Nature Park in Croatia. Green nodes belong to the "core" group, pink nodes belong to the "periphery".

4 http://www.analytictech.com/ucinet/help/a8lapo.htm

Relations between groups: if nodes belonging to the same group are collapsed into one node that represents all of them, a network with few nodes and many parallel edges is created. If the parallel edges are merged into one weighted edge (where the weight equals the sum of the edges collapsed), relations between groups can be visualized. Sometimes it becomes apparent that certain groups are tightly connected while others are separated or just loosely in communication (See figure 7.). This can be calculated using iGraph[5] or can be reproduced manually in Microsoft Excel.

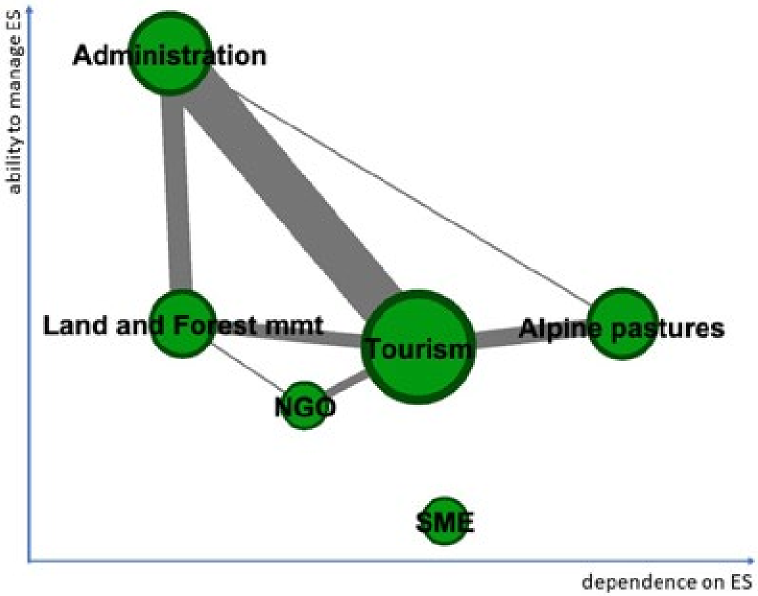

Fig. 7: Group-relations in the Kalkalpen National Park in Austria. Node size represents the number of nodes in the group, edge thickness represents the weight of the edge (number of connections). Note that some groups are not connected. Position of nodes represent their power relations.

5 https://igraph.org/r/doc/contract.html

Challenges

Protection of personal data

Social network analysis is a powerful tool, which offers often convincing explanations in issues of natural resource management. At the same time, this method requires personal data from the respondents. **Confidential treatment of the survey is extremely important. Besides the team analysing the data, nobody should get access to the data being processed.** Compiled network information can be drawn in graph form, where groups and patterns of connections can be observed, but **on these figures, no names should be revealed.** In some cases, people familiar with the region try to guess who is who on an anonymous network graph. Even if their guesses are right, they should not be given any feedback on the identity of individuals. Data collection and handling should follow the relevant national and international regulations (GDPR).

Data collection

It is not easy to quantify how many survey responses are necessary to get "enough" data for the network. Representative sampling in SNA is not a useful concept since data items are not independent. Usually, highly connected players will appear in the graph since they have a higher probability to be mentioned by one of the local players. It is a good idea to encourage expected high-degree nodes to fill in the survey. Members of all groups have to provide information. The best results are achieved where close to 100 responses (or more) are collected, but sample size depends also on the size of the area in question, number of settlements, number of inhabitants, etc. In smaller communities, it may be an achievable goal to have everyone in the network. Theoretically, this is the best solution.

SNA

For a beginner, Gephi is an accessible tool for SNA. UCINET and especially iGraph have a much steeper learning curve. Background knowledge can be found in the references section. Most of the work described in this document can be completed using only a spreadsheet editor and Gephi.

Quality Check

The quality of the results can be assessed together with the stakeholders. Their reflection on the conclusions may verify or question the results – but it is also possible that an accurate result may surprise them, thus verification of the results has to be a dialogue between the research team and the stakeholders. Small networks usually show a familiar picture to the stakeholders. More detailed graphs can be more surprising even for locals – these surprises may provide important input for those who are thinking about local naturalresource management.

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Mapping of ecosystem services

Eszter Tanács, Ágnes Vári, Béla Kuslits, Tamás Frank, Ildikó Arany, László Zsolt Garamszegi

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Introduction

The capacity of a landscape to supply specific ecosystem services (ES) usually depends on several different factors, which can be mapped: grabbed by spatial models specifically designed for the purpose (Burkhard & Maes 2017). The key principle of mapping described herein is the ES cascade concept (Potschin and Haines-Young 2011) which should be followed in interpreting and measuring the flow of services from nature towards society. Another one of our guiding principles is the participatory approach (Davies & Dwyer 2008) where local experts actively take part in the model development (see more about both at Scientific Background). This allows the mappers to reflect local knowledge about the capacities and the opportunities and obstacles of the landscape with reference to the provision of ES.

Mapping of ES is a central part of the ES assessment process; however, it cannot be performed in an isolated way without a proper preparation in terms of the ecosystem mapping, stakeholder involvement and the identification of relevant ES. The results of the ES maps have to be interpreted and synthesized first, before they can be considered in land use discussions.

Goal of the document

In this document, we will first describe the general structure of the rule-based matrix model that we found most useful for a participatory ES assessment at the regional level. Thereafter, we will summarize the models and the methodology for a few selected items, which were most frequently chosen during the discussions and the testing and learning activities within the ECO KARST project , to wit: biodiversity as an important dimension of ecosystem condition (EC) and 8 specific ecosystem services (ES) at the capacity level of the cascade. Most of the specific models follow one specific method (rule-based matrix method). Alternative solutions will be presented for some of the cases nevertheless

Examples of the primary outputs (indicator maps) are derived from the ECO KARST results to illustrate the methodological choices and troubleshooting during the tailoring and testing of the methods. Building on a limited number of ES and pilot areas, the ES models detailed herein cannot be regarded as comprehensive. However, we believe that our experience is transferable also to services not described in this document .

Place in the assessment process

Figure 1 shows the situation of ES mapping within the schematic structure of the ES assessment.

The actual ES mapping has to be preceded by the delineation of the area to be assessed, the selection of the relevant ecosystem type categorisation and the creation of an ecosystem type (ET) map using the selected categorisation, which is described step by step in Chapter 1. In Chapter 2, we introduce a list of ecosystem condition components and ecosystem services likely to be found in the terrestrial karst protected areas of the Danube region, an environment in which methods were tested during the ECO KARST project. We also introduce steps to choose the most relevant of these items, specifically for the area to be assessed, thus identifying subjects of the ES mapping. Identifying relevant stakeholders is another crucial step before mapping ES, which will ensure effective use of their knowledge in the process. The methods suggested for exploring power relations among stakeholder groups, analysing social network of local stakeholders to find key players, communication gaps and patterns of information sharing are described in Chapter 3. The assessment of ES is carried out by evaluating the economic value of ES, as described in Chapter 5: methods for assessing the actual use of the services as well as their economic benefits. Figure 1 summarizes the process and highlights the position of mapping in it.

Skills required to complete

In order to successfully apply the methods described herein, experience with ES assessment is an advantage, but not a requirement. However, it is necessary to have some background knowledge about the landscape of the assessed area, including its main ecosystems, land use types and stakeholder groups. It is also an advantage if the user has an already established social network in the area and if they have good moderator skills. Some experience in GIS is necessary, depending on the model complexity (Tiers - see at Scientific background). Tier 1 level mapping requires only basic GIS skills but for models at Tier 2 some advanced techniques may be required. The mapping is not software-specific – any software capable of adequately handling spatial data may be used. In the course of our work, we mainly used ArcGIS (version 10.2), QGIS (version 2.14) and in some cases SAGA GIS (version 6.3).

Scientific background

The notion that humans depend on nature and its different features and "services" that it provides is century-old. Today, ecosystem services are regarded as an independent discipline that developed rather fast since the first use of this term (supposedly) in 1981 (Ehrlich & Ehrlich), and the well-known and most discussed publications, such as those of Costanza et al. (1998). The simple use of this term/concept was soon complemented with quantification approaches (e.g. Boyd & Banzhaf 2006). Setting up models that show the number of ES provided and their location on the maps is an important development, which contributes significantly to the evaluation of possible management options and optimal decisions. In recent years, the importance of assessing and mapping ES has been emphasized in policy recommendations and formulated as directives (see EU Biodiversity Strategy Action 5). Parallelly, more and more guidance on how to implement the mapping of ES has been elaborated as a result of the work done by the EU MAES working group (Maes et al. 2013, 2014, 2015, 2018), and based on the suggestions from the researchers (Burkhard & Maes 2017). In line with the requirements applicable to all EU Member States, the main focus was placed on the guidance concerning the mapping of ES at the national level. Experience of the member states accumulates as more and more states accomplish this aim (e.g. Becerra-Jurado et al. 2015). A number of modelling approaches have been elaborated for certain ES, which however often require fine-scale data and expert knowledge on the modelling tools (Bagstad et al. 2013, Lüke & Hack 2018). Detailed guidelines on how to work out models for mapping ES, for a comprehensive set of ES and especially at the regional scale, were less focused on.

The concept of ES was soon complemented with the concept of ecosystem condition (EC). EC maps show the key ecological characteristics specific to individual (or groups of) ecosystems that are able to illustrate the cumulative effect of pressures on ecosystems over time. Similar concepts (ecosystem health, integrity, state, and recently conservation status) have been used for decades in traditional conservationist approaches. In the ecosystem services framework, the emphasis is put on the ecosystem condition , which is vital to human health and well-being by affecting the ability of ecosystems to provide services. The Millennium Assessment (MA 2005) defined the ecosystem condition as "the effective capacity of an ecosystem to provide services, relative to its potential capacity". A more recent definition of the ecosystem condition by Czúcz and Condé (2017) is "the overall quality of an ecosystem unit, in terms of its main characteristics underpinning its capacity to generate ecosystem services". Figure 2 (originally in MAES 2013) shows the relationship of the ecosystem condition and ES.

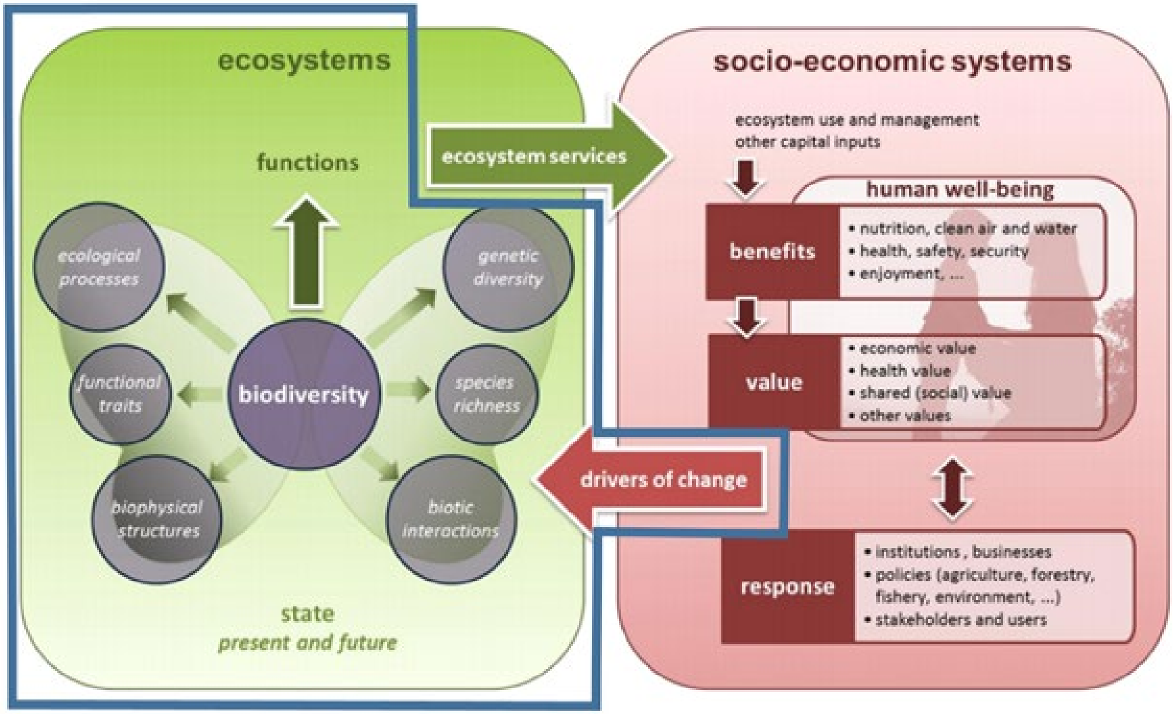


Figure 2: The content of the ecosystem condition assessment as suggested by Maes et al. (2015)

If we want to assess the ecosystem services provided by the specific area, we have to understand first the concept of the ES flow from nature to society, which can be seen through various stages of a four-level model called the 'cascade model' (Figure 3) (Potschin & Haines-Young 2011, Czúcz et al. 2018). The starting point is rather technical: we need to have a spatially explicit account of what kind of ecosystems there are in the study area, which is represented by an ecosystem type map (level 0), classifying each land unit into the categories of an ecosystem typology. The condition of ecosystems is the first level in the ES flow, that fundamentally determines the ecosystem's internal processes and operation. Appropriate condition enables ecosystems to provide services (level 2). At this point these are potential services, or in other words, ES capacities. As soon as this capacity is really utilised, we talk about the actual use (level 3) of the ecosystem services. The benefits of the services used then appear in the form of maintained or increased well-being in the society (level 4).

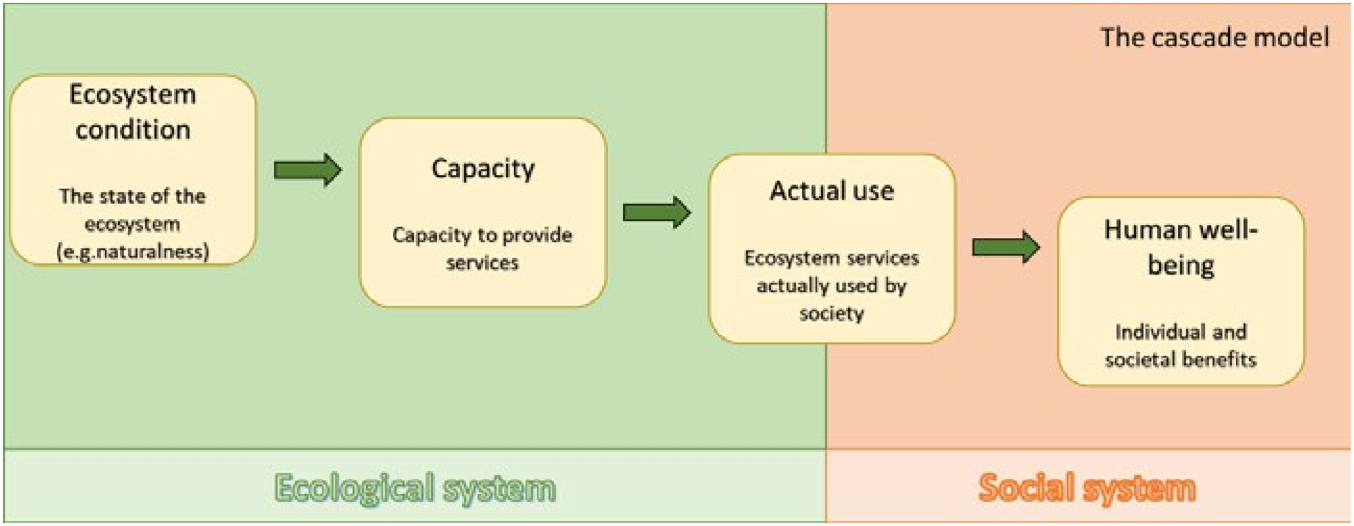


Figure 3 The cascade model of the ecosystem services

Model types and the matrix model approach

A detailed landscape-level spatial ES assessment, i.e. ES mapping, requires a, models. Models link biophysical data spatially represented by input maps with variables (indicators) describing the capacity of the landscape to provide a specific ES. Models can have different levels of complexity, which are also called Tiers in the scientific literature (Grêt-Regamey et al. 2015).
The simplest models (Tier 1) are compiled with local experts using the ES matrix model, assigning values to certain land use/land cover classes for each ecosystem service. Instead of data, the necessary information is provided directly by experts or stakeholders in the form of synthetic judgements, in an iterative process which incorporates the intuitive knowledge of the local experts in a transparent way (Burkhard et al. 2010, Jacobs et al. 2015, Czúcz et al. 2018). Experts can fill in the matrix in consensus or one by one, as (partial) individual filling in (Campagne & Roche 2018), and estimate the relative capacities of the ecosystem type (ET) categories on an ordinal scale.
Besides the baseline expert matrix, which relies only on the ecosystem type map, more complex indicators can be calculated using either a statistical model or a set of rules linking the value of the indicator to additional background variables. This is the extended matrix model, or rule based model (Tier 2), which can be applied for most of the ES in the following chapters. Models can be refined based on expert recommendations and international literature, so that the models take into account additional environmental factors (e.g. the altitude of a given location). As a final step, if possible, the resulting scores are converted to physical quantities (e.g. m3 wood/ha/year).

A general overview of the main steps of modelling and mapping of ES is shown in Figure 4.

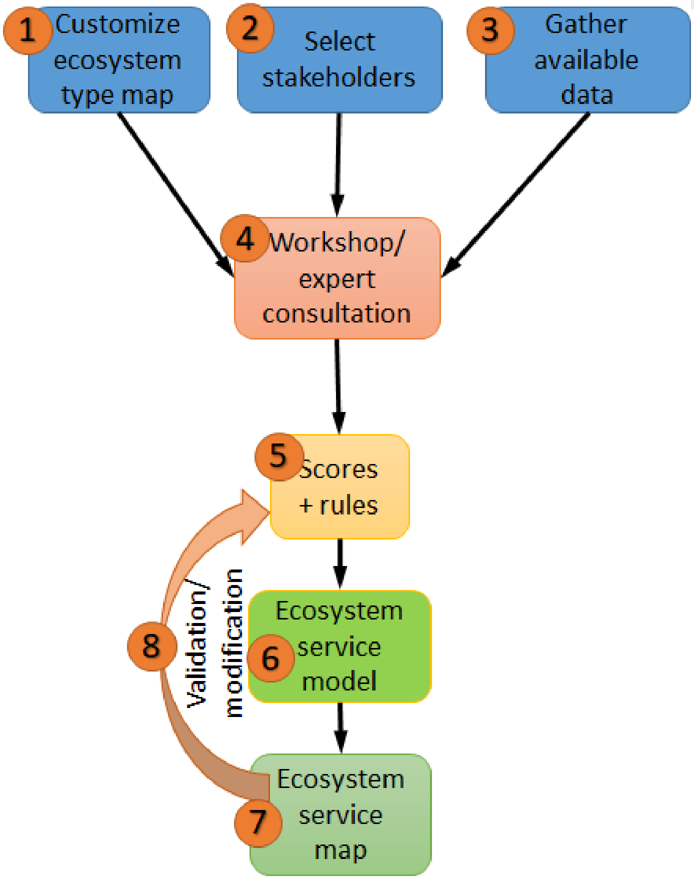


Figure 4. General overview of modelling and mapping of ecosystem services

Levels of expert involvement

Different views exist on who is to be regarded as an expert. We have formulated the following definition based on Flyvbjerg (2001):

> A person qualifies as an expert if he or she 1) works in direct contact with the ES in question, 2) personally experiences variance in ES performance depending on season, year and location, 3) has the competence to make ES management decisions that affect the state of the habitat and the actual yield of the ES.

Involvement of experts is possible at the following levels:

- **Individual consultations**
  Individual experts are consulted at the early phase of the process during customization of the ecosystem types and data pre-processing to formulate different model components, i.e. rules (see at: The general process of mapping Ecosystem condition (EC) and Ecosystem services). Experts can help in the creation of categories and give advice as to the availability of spatial data. Individual consultations can be used, after the expert mini workshops, to calibrate and fine-tune the biophysical measurement units calculated by the models.
- **Expert mini workshops**
  The actual models are set up for the purpose of the expert mini workshop, and include the scoring of the ecosystem types, adoption of rules and fixing of the relative scale to the estimated biophysical measurement units. 2-4 experts should be invited to the expert mini workshops (a group of people who work on different places, and who are not subordinated to each other).
- **Stakeholder workshop**
  The draft maps are created along the ES models set up in the mini workshops and calibrated in line with the individual consultations. Thereafter, the maps can be presented at the stakeholder workshops. In these workshops, feedback on the maps is gathered from a wider representation of stakeholders, and simple validation is performed.

The general process of mapping Ecosystem condition (EC) and Ecosystem services

The precise workflow of creating a map out of the input data will differ for each model, which is presented for a number of selected ES in the following chapters, but generally it will involve some or all of the following steps:

1. customizing the ecosystem typology and creating an appropriate ecosystem type map,
2. creating a simple matrix model by assigning base scores (relative values) to the ecosystem types,
3. extending the model: identify additional spatial variables relevant for the ES and integrating the additional variables into the ecosystem service model in the form of rules that modify the base scores.

These steps are further elaborated in the section Workflow to provide general guidance, while specific cases are discussed in the section Specific EC and ES models. Technical issues and guidance are written in italics.

Data needs

Data requirements depend on the target ES, but will most probably be based on an ET map. The specific data needs are listed for each ES, based on several pilot experiences. Except for the ET map, it is unlikely that all of these data are necessary for a single model. Selection of the relevant variables for a concrete map should be based on expert decision. In most cases, the number of variables incorporated is also constrained by limited capacities and data availability.

Workflow

1. Customize the ecosystem type map according to the ecosystem service in question

This is an optional step, the aim of it is to have an ET classification which reflects the actual differences in the ET supply capacities, but avoid more details than what is necessary for this purpose. Depending on how fine the basic ET categories are (see more at: Chapter 1 - Identification of Ecosystem Types), this step might mean either a simplification or a refinement. Simplification reduces the number of categories to be considered. It is most easily done by merging some classes. If a hierarchical classification is used, for certain ecosystem services we can simply consider using a higher-level categorisation of our maps (see Figure 5 for an example of EUNIS multilevel classification). It is also possible to choose other considerations on how to merge the categories according to the ecosystem service to be mapped.

Technically the simplest way of carrying out this merging of categories is to create a conversion table (old categories → new categories) and join it to the original ecosystem type map layer. This would not necessarily mean a physical merging of habitat patches, only a reclassification added to the attribute table of the map (Figure 5).

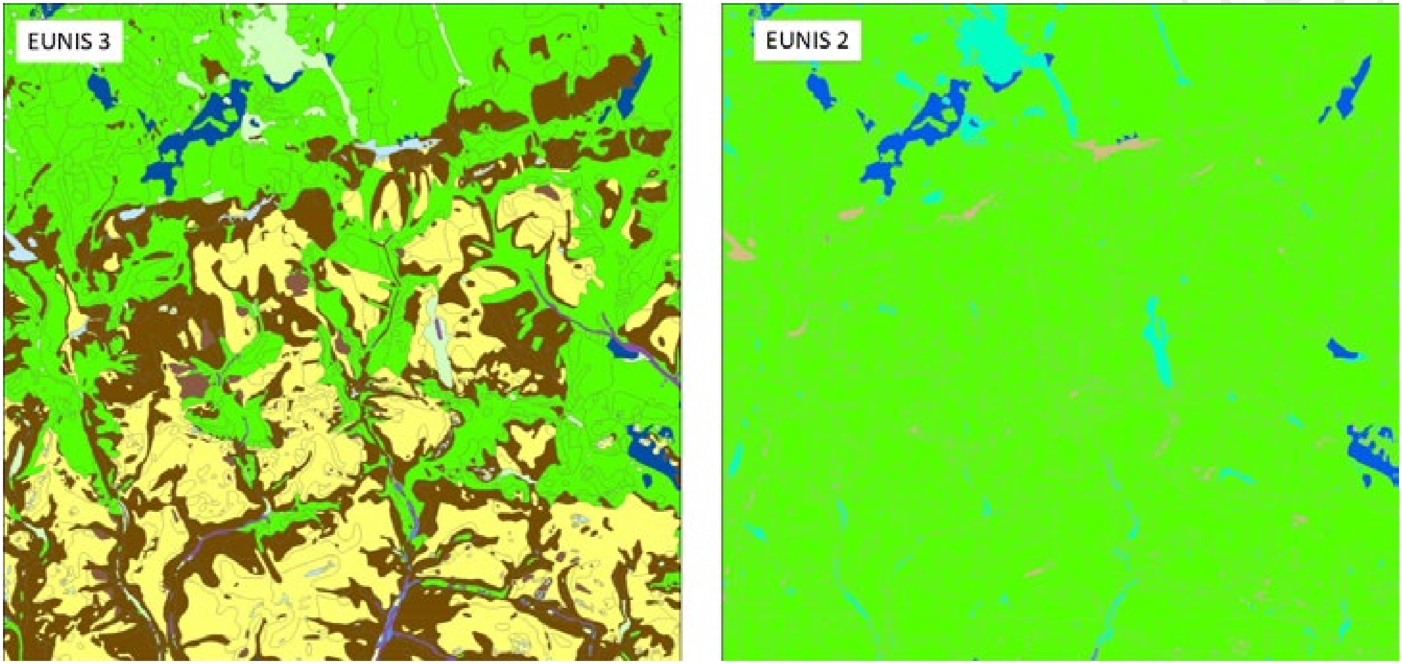


Figure 5. Example of simplification (deciduous forests, which at EUNIS level 3 are divided in 3 different categories, are one category at level 2 - represented by the green colour)

Sometimes customizing the map would mean a refinement. Evaluating some ecosystem services in depth may require more detail, so some habitat types might need to be divided (e.g. grasslands into meadows and pastures), if finer data is available. This would normally mean involving additional data (either existing GIS datasets with more detail, or remote sensing methods).

2. Assign values (base scores) to habitat types

In this step, each ecosystem type is assigned a score by local experts in order to describe the ability of that specific type to provide a specific ecosystem service. It is called 'matrix model', because when more than one habitat is scored for more than one service, the resulting table is a matrix of scores. However, when we are mapping one service at once, the table we need is simply a list of habitat types, along with the scores that belong to each type.

Therefore, technically this step can be combined with the previous one - the scores can be added to the conversion table as a separate field - or another table can be created containing the customized categories and the assigned scores.

3. Extend the model

In most cases, the ET categories are not the only variables that determine the ecosystem's capacity for a certain ES. If we want to reflect reality more precisely, we can decide to refine our model by including the effect of further environmental factors (e.g. the effect of altitude, slope steepness, grazing intensity, entrance of caves) in the form of rules. The rules can vary from simple formulas to complex statistical or biophysical models; however, the scope of this Guide is limited to simple rules.
The general way for this is to identify categories or ranges of a certain variable and create rules (additive or multiplicative formulas) for each category that modify the base score of the ET.

*Rules define the specific value to be added to, reduced from or multiplied with the base score that was given previously to the ecosystem type. This method is best used when the modifying effect of a variable is similar across all ecosystem types. Sometimes this is not the case: for example, grazing intensity may only be considered a relevant variable on certain grasslands, or soil fertility may have different effects on honey provision on different (groups of) ecosystem types. In such cases, rules must be differentiated along the most characteristic ET*variable combination types.*

Some pre-processing of the different variables may be necessary. If, for example, the modifying factor is represented as a continuous surface (e.g altitude, or slope steepness) or has too many categories, it may need to be reclassified into relevant categories (see Figure 6). The relevant categories should be defined by the local experts.

Assign a simple modification value to each class of the modifying environmental factor in a separate table and then join this to the ecosystem type map already containing the base scores. Final scores will result from adding all modification values to the base scores. If working with raster files, the raster containing the base scores and the raster(s) containing the modifying values can be added up directly.

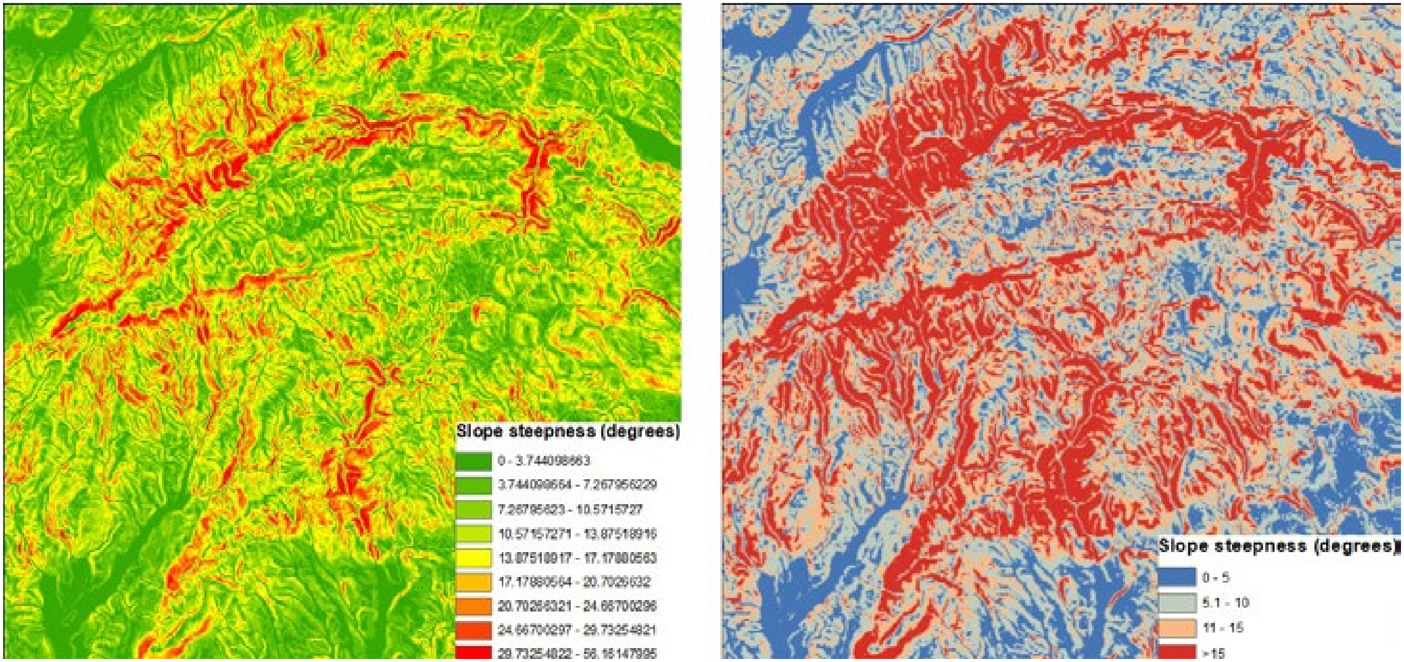


Figure 6. Example of reclassification - slope steepness

*Alternatively, if a variable is highly determinant and diverse in its effects at the same time, base scores may be re-defined in a matrix, assigning revised values to each ET*variable combination. Some combinations may not be relevant, these of course need no modification.*

Define the existing (and the relevant) category combinations. The best way to do this for both raster and vector files is by using Tabulate Area (ArcGIS) or an equivalent technique. This results in a matrix of all possible category combinations and their area. Combinations with a very small area may not be relevant or even just errors.

Create and fill in a list or a matrix with scores for each relevant combination of categories. Table 1 and Table 2 show an example of a matrix and a list.

When there is more than one factor included in the model, one or both of the above techniques may be necessary. Some factors may be more important than others, or the order of adding them may have some significance. In order to avoid repeating the same processes a lot, and also for better documentation, it is advisable to create workflows e.g. in ArcGIS ModelBuilder (QGIS too has a graphical modeler to help automate processes).

EUNIS type (level3)	>700 m	0-250 m	250-700 m
Acidophilous oak-dominated woodland			
Active opencast mineral extraction sites, including quarries			
Beds of large sedges normally without free-standing water			
Beech woodland			
Broadleaved deciduous woodland			
Closed non-Mediterranean dry acid and neutral grassland			
Coppice and early-stage plantations			
Early-stage natural and semi-natural woodlands and regrowth			
Highly artificial broadleaved deciduous forestry plantations			
Highly artificial coniferous plantations			
Intensive unmixed crops			
Large-scale ornamental garden areas			
Low and medium altitude hay meadows			
Medio-European rich-soil thickets			
Mesic grasslands			
Meso- and eutrophic oak, hornbeam, ash, sycamore, lime, elm and related woodland			
Mixed forestry plantations			
Mixed riparian floodplain and gallery woodland			
Moist or wet eutrophic and mesotrophic grassland			
Moist or wet tall-herb and fern fringes and meadows			
Mountain hay meadows			
Perennial calcareous grassland and basic steppes			
Residential buildings of city and town centres			
Residential buildings of villages and urban peripheries			
Rich fens, including eutrophic tall-herb fens and calcareous flushes and soaks			
Seasonally wet and wet grasslands			
Springs, spring brooks and geysers			
Submediterranean deciduous thickets and brushes			
Surface standing waters			
Temperate thickets and scrub			
Temperate-montane acid siliceous screes			
Thermophilous deciduous woodland			
Urban and suburban industrial and commercial sites still in active use			
Vineyards			
NoData			

Table 1: Matrix format example for simultaneously scoring habitat type and altitude. Scores are to be written in the empty cells.

Ecosystem type and altitude combined categories	No of polygons	score
Acidophilous oak-dominated woodland - >700 m	7	
Acidophilous oak-dominated woodland - 0-250 m	18	
Acidophilous oak-dominated woodland - 250-700 m	1343	
Active opencast mineral extraction sites, including quarries - >700 m	1	
Active opencast mineral extraction sites, including quarries - 0-250 m	9	
Active opencast mineral extraction sites, including quarries - 250-700 m	28	
Beds of large sedges normally without free-standing water - 0-250 m	3	
Beds of large sedges normally without free-standing water - 250-700 m	25	
Beech woodland - >700 m	1707	
Beech woodland - 0-250 m	35	
Beech woodland - 250-700 m	8477	
Broadleaved deciduous woodland - 0-250 m	8	
Closed non-Mediterranean dry acid and neutral grassland - 0-250 m	10	
Closed non-Mediterranean dry acid and neutral grassland - 250-700 m	46	
Coppice and early-stage plantations - >700 m	1	
Coppice and early-stage plantations - 250-700 m	2	
Early-stage natural and semi-natural woodlands and regrowth - 0-250 m	4	
Highly artificial broadleaved deciduous forestry plantations - 0-250 m	20	
Highly artificial broadleaved deciduous forestry plantations - 250-700 m	134	
Highly artificial coniferous plantations - >700 m	421	
Highly artificial coniferous plantations - 0-250 m	48	
Highly artificial coniferous plantations - 250-700 m	1142	
...		

Table 2: List format example for simultaneously scoring habitat type and altitude (only part of the possible combinations is shown).

4. Validate the draft map on the stakeholder workshop

Validating the obtained results with stakeholders is generally a last step of great importance (Campange & Roche 2018). While in most cases only limited data is available for quality check of ES models and maps, this step enables experts to review their own scorings/evaluations and fine-tune them.

Quality check

1. Uncertainties of the results might be high due to the uncertainties of the input maps (habitats and soil) - for many models there might not be any appropriate methods to assess uncertainty.

2. The transformation to biophysical units might add to uncertainties, in many cases this might not even be possible, even though if achieved, it might be one of the ways to get your models validated.

3. An important factor in the quality of the output maps is the level of detail the picture offers on the ES. This depends on the resolution of the input maps - the end result will be as accurate as the weakest input dataset . It is useful to compare the data resolution with the resolution of the intended management decisions. Ideally, the map justifying the decision should be more detailed than the decision itself. This applies to both spatial and temporal resolution of the data, and also applies to the expected errors on both sides. If the ES map is not detailed or accurate enough, it should not be used as a decision support tool.

4. A problem that often emerges is missing data. While ES modelling in theory would list several necessary datasets, they might not all be available , especially if we want high quality and relatively recent datasets. Sometimes financial constraints prevent mappers from obtaining one or more input datasets. The entire mapping process may be jeopardized in some of those cases., while in others only the model quality or accuracy decreases. In the latter case, it is important to think about how the poorer model would change the outcome compared to the originally envisioned mapping process, and how the limited model may cause problems when such an ES map is applied in practice.

Specific EC and ES models

The following section presents the step by step mapping of some specific aspects of EC and types of ES. Examples of implementation - depending also on data-availability - are provided.

Ecosystem condition

The role of the ecosystem condition (EC) maps is two-fold. Besides indicating the overall effect of human activity on the ecosystems (and thus, indirectly, the long-term sustainability of that activity) they can also form part of the mapping of ecosystem capacity to deliver services. Although here EC mapping is discussed together with the ES models, it is usually considered a separate step in the ES mapping process (Maes et al. 2015).
In order to represent and map the general condition of the ecosystems, there are several approaches depending on data availability. MAES distinguishes two main (complementary) approaches to assessing condition: an indirect approach, based on the evaluation and mapping of the pressures acting on ecosystems, and direct assessments of habitat condition, biodiversity and environmental quality. Ideally, information from both approaches is available, and data sets can be used for comparison and validation and for interpreting how pressures affect current conditions (Maes et al. 2015, Maes et al. 2018).
Article 11 of the EU Habitats Directive refers to the obligation of the Member States to monitor the conservation status of all habitats (as listed in Annex I) and species (as listed in Annex II, IV and V) of Community interest. Article 6 also requires the assessment of the "degree of conservation" of sites according to criteria in Annex III, of a habitat type or species at a specific site (Evans and Arvela 2011). Member States are free to choose their methods of data acquisition and to determine the reference values for the categories so there are a multitude of methods ranging from expert estimates through synthetic expert estimates based on defined criteria or modelling based on partial sampling to complete surveys (Alberdi et al 2019). Either of these methods or the resulting data/qualifications can be used for direct condition assessment if available for the area in question.

EC Method 1 – Zonation

Zonation is an example of how a pressure indicator may be applied as a proxy of condition (although, strictly speaking, level of protection refers to the lack of pressure). In the protected areas (national parks, nature parks and similar), zonation based on previous assessments and/or expert opinions is usually already available. There are often differing regulations regarding the use of the area and its resources (e.g. in Biosphere reserves, Natura2000 areas, forest reserves) within the zones. As a very basic approach, one can assume that the delineation of the zones also reflects the ecosystem condition (the areas deemed most valuable within a protected area are supposedly the most natural ones). One can also assume that a specific protection status will lead to improvement (or at least not deterioration) of conditions as compared to non-protected areas. This approach is mainly recommended if there is no other information available, as it usually does not allow for detailed analysis at a fine spatial scale. Zones are often designated as compact patches encompassing areas in different state. As detailed spatial data on ecosystem condition is often hard to come by, this approach is sometimes used in ES studies as a proxy (e.g. Valecillo et al. 2019, Zulian et al. 2013)

Data needs

- Map of protected areas with zonation.

Workflow

Assign scores to different zones according to how intact nature is supposed to be within them.

Challenges

No challenges, very simple.

Quality check/Pros & cons

While including some kind of an EC representation into assessment is the easiest approach, it's major setback is the lack of direct possibility to check the results when there is no data available. The suitability of the zonation maps as proxy for ecosystem condition depends on the considerations of the designation and the restrictions on land use they imply. Designating protected zones is sometimes just an obligation to be fulfilled or it may reflect a desire to improve ecosystem condition in the area in the future. In these cases, the protected zones may include areas that are (at present) not in a good condition. The borders are often the result of some compromise between major stakeholder organisations. However, if the zonation is based on a detailed research and/or land use is strictly regulated within the zones, it can reflect condition well. Quality check may include an overview of related regulations and the declared aims and considerations of the designation of the zones. There may be also research available in the literature on the effectiveness of different types of protection.

Examples

This approach was used by several of the EcoKarst pilot areas in conjunction with other methods. Apuseni Nature Park combined the 10x10 km distribution maps of Natura2000 habitats and species with added modifying factors, park zoning being one of those. In Tara National Park, the zoning was used to provide base scores (see the among the Examples below). In Nature Park Žumberak – Samoborsko gorje, zones were also scored and used as a modifying factor.

EC Method 2 – Biodiversity

It has been recognized that biodiversity affects the properties of ecosystems and therefore the benefits that humans obtain from them (Diaz et al. 2006). Although the precise nature of connections between biodiversity and ecosystem services (especially multiple ES) is still not clear (Smith et al. 2017), one way to examine the overall sustainability of the management of an area's ES is to monitor biodiversity. Biodiversity as such is famously difficult to quantify, and there are many different approaches. Often the species richness of one or more species groups is used. Locally, on an ecosystem level scores can be given based on the deviation from an expected species list in undisturbed or pristine systems. There are also approaches where local biodiversity (or, in time, its changes) is evaluated using endangered species or habitat lists (Schneiders et al 2012). Carignan and Villard (2001) provide some general guidelines on the challenges and methods of choosing indicator species.

Here we describe a method based on the condition mapping of Luxemburg (Becerra-Jurado et al 2015), which can be adapted in other areas as well. In this case base scoring defines the naturalness of habitat types relative to each other - based on the assumption that some ecosystem types (usually those hardly accessible or unsuitable for production) are by default less affected by anthropogenic activity than others and therefore usually in a better condition. The modifying factor, which is based on species occurrences, serves to further differentiate between patches of the same ecosystem type, reflecting the state of each particular polygon. The workflow imitates methods used in field surveys.

Data needs

- ecosystem type map
- a list of species to be considered (for the whole area or for each ecosystem type)
- number of species observed in each habitat patch (within the pre-selected pool of species)
- (approximate) data gap mask for the species data

Workflow

1. Data pre-processing:
   1.1. Gather available (point) data of species occurrences/observations.
   1.2. Try to identify data gaps (areas where the lack of occurrences is a result of the lack of observers/observing activity rather than the lack of species).
2. Model building (preferably by consulting with biodiversity experts):
   2.1. Assign a base naturalness score (e.g. from 1-5: worst →best) to each habitat type based on the experts' decision.
   2.2. Define the species pool to be used for refinement (can be generic or ecosystem type-specific) - choose species or species groups, which are good indicators of the ecosystem condition (invasive species can be chosen as negative indicators).
   2.3. If the ecosystem type-specific species are used, assign separate pools to the main ecosystem types.
   2.4. Assemble the point data of the chosen species: calculate the number of relevant species within each habitat patch.
   2.5. Assign modifying rule to the number of species within each habitat patch (e.g.: 0 species: -1; 1 species: 0; 2-3 species: +1, ...).
   2.6. If invasive species are used, assign negative modifying rules,
   2.7. Fill in data gaps with the help of the experts.
3. Create a draft map based on the established model.
4. Create the data gap mask (no sampling/monitoring effort in the area: 0 – sampled area: 1)
5. Check the results and refine the rules, if necessary.

Challenges

The main challenge of this approach is a general lack of high-quality, consistent datasets. If the data is derived from citizen science databases or assembled from individual observations by e.g. rangers or local experts, it needs to be handled very carefully. In these cases the absence of observation does not necessarily mean the absence of the species in question – it can simply be a data gap.
Possible solution: it is possible to create a simple complementary data gap map. For identifying data gap areas, experts (the data owners or others with good knowledge of the area) should be consulted, as they might be able to fill in some of the data gaps.
Even if there is a suitable amount of high-quality occurrence data, the size of the spatial units used for aggregation (e.g. the habitat patches) may affect the number of species.
Possible solution: break down polygons that are too large (e.g. by segmenting aerial or satellite imagery) or use a grid instead.
How to choose the 'pool' of relevant species for each major ecosystem type is also an issue. Overall species richness may even increase with degradation; therefore, the choice of the wrong species can easily lead to non-relevant results.

Quality check/Pros & cons

Quality check in the case of these maps is very difficult. Experts with extensive field knowledge can provide useful feedback. Comparing results of different approaches may also be useful.

Example

In Bükk National Park, each habitat was scored according to its general naturalness (scale 1 /lowest/ to 5 /highest/) by the experts of the NP (Figure 7). As a modifying factor, the number of protected vascular plant species occurring in each habitat polygon was used (rules: 1-4 species/polygon = +1 point; 5-10 species/polygon = +1.5 point; 11-20 species/polygon = +2 point; >21 species/polygon = +3 point). Protected vascular plants were considered good indicator species by the NP experts: understorey plants in forest habitats reflect naturalness while grassland species in open habitats mostly reflect to the management regimes in the past - or present land use.
The resulting map highlights biodiversity hotspots and generally those areas which are supposed to be valuable from the conservation point of view. When analysing the results of ES-mapping, especially when evaluating trade-offs and sustainability issues, it is very important to consider ecosystem condition - planning should aim to keep and possibly extend those areas in a good condition. Condition maps can also serve as inputs for different ES models.

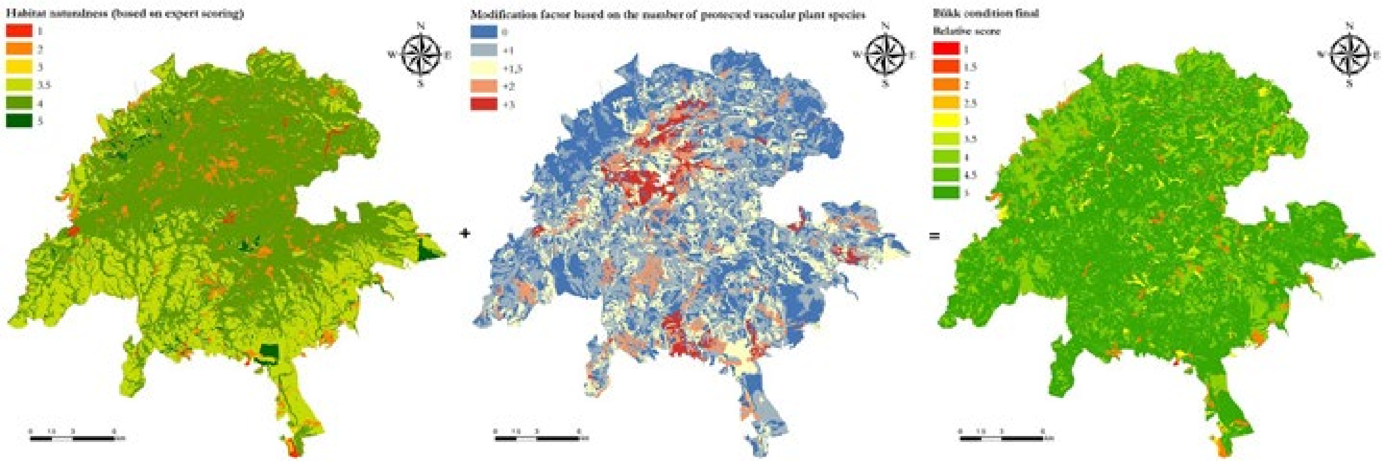


Figure 7. The components (habitat naturalness, modifying factors based on the number of protected vascular plant species) and final result of condition mapping in Bükk NP.

EC Method 3 – Other specific and/or combined methods

There are a lot of ways and methods to describe ecosystem condition. In EcoKarst the quantity and quality of available data was hugely different for all the pilot areas therefore the methods they chose were also very varied.

Example

Here we demonstrate another example for the evaluation of the ecosystem condition from Tara National Park (Figure 8). The basic input data were the zoning of the park and the ecosystem type map. The base scores were assigned to the zones. The strictest protection zone received a score of 15, as some of the most valuable habitats of endemic plant species (primarily Serbian spruce Picea omorika but also endangered animal species) can be found in this part. According to strict conservation laws, these areas are mostly outside direct human influence. The second zone was assigned a score of 10 and the third a score of 7. For the forested areas specific indicators were calculated from the forest inventory. Structural diversity was approximated by dividing the trees into dbh (diameter at breast height) classes and Shannon diversity was calculated for these classes. Scores of 0-2 were assigned based on the resulting diversity values, depending on the habitat type. The amount of deadwood was also used as a modifying factor: over 20 m^3/ha a score of +2; from 10 to 20 m^3/ha a score of +1 was assigned. Non-managed compartments and subcompartments received a score of +4. For nonforest habitat types, the NATURA 2000 distribution of sites was used; habitat patches were assigned with 0 or 5 in line with the list of priority habitats.

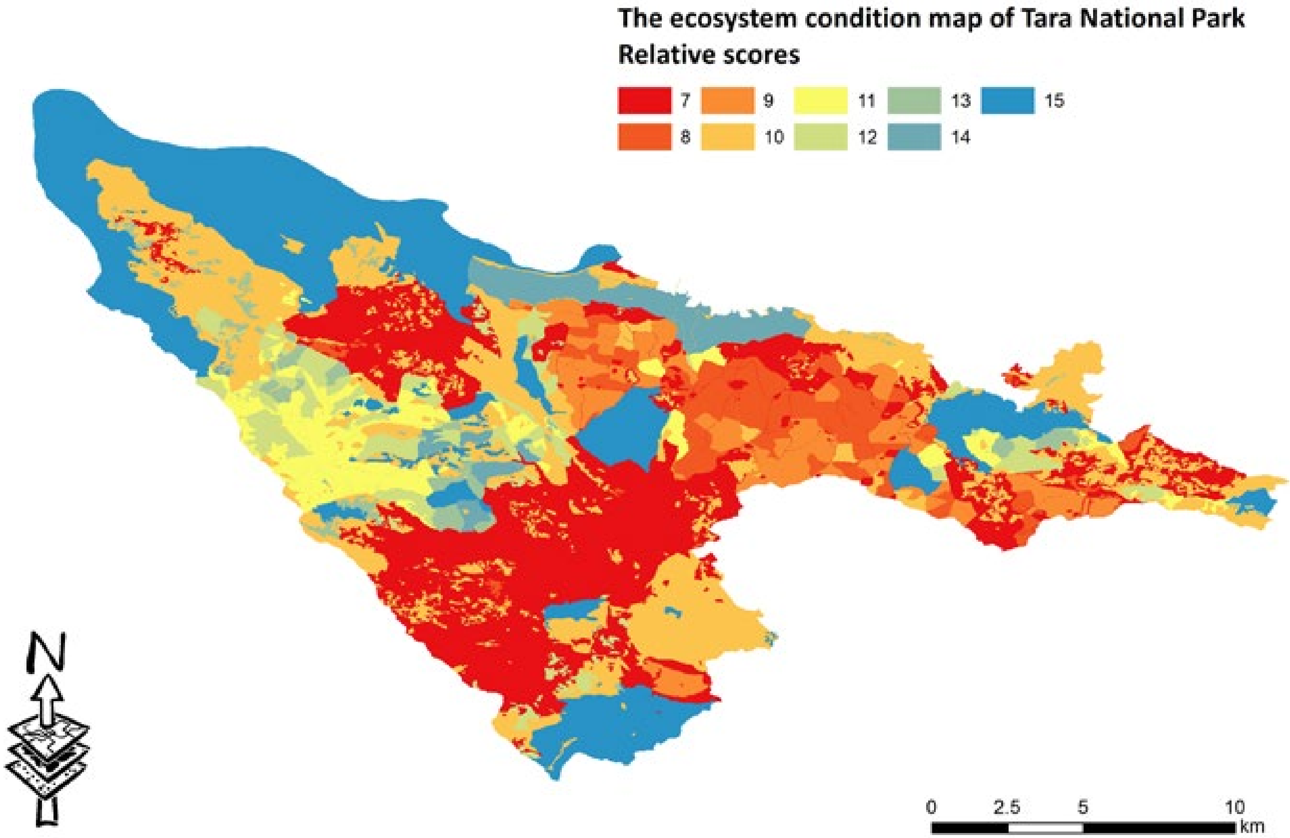


Figure 8: Ecosystem condition map of Tara National Park (relative scores) (by Branko Bezarević and Aleksandar Djurić).

Water quality protection

Definition: the capacity of ecosystems to retain water and thereby filter pollution, especially forms of nitrogen.

Karstic aquifers have a very limited self-purification capacity as their recharge is typically very fast - it mainly occurs through concentrated zones of infiltration (fractures, sinkholes etc.) (Milanovic 2004) Therefore they are especially sensitive to surface pollution. While water quality can be described by a number of different variables, such as concentrations of chlorophyll-a, toxic contaminants (like heavy metals) or bacteria, one major and very common pollutant is nitrate from agricultural effluents. Nitrogen is removed from water primarily by denitrification or by adsorption to sediment organic matter, sediment sorption, and plant and microbial uptake within soils, ground waters, riparian zones, floodplains, rivers, lakes and estuaries. These systems act as successive filters, where the above-mentioned processes of elimination take place (Grizzetti et al 2015). Thus water residence time in the whole surface water system of river basins significantly affects the retention of nitrogen (Hejzlar et al. 2009). Our expert models were built on the assumption that water residence time is higher at sites where surface vegetation is dense enough to retain more water, by decreasing run-off. With the increase of residence time, nitrate retention can also be assumed to be more significant. As we had no access to measured data to calibrate GIS-based hydrological models, we established a simple model designed with the help of soil scientists.

Data needs

- Ecosystem type map
- Satellite imagery (suitable for the calculation of NDVI), possibly with a spatial resolution of at least 30 m
- Digital Elevation Model of the area

Workflow

1. **Data pre-processing**
   - **1.1.** NDVI (Normalized Difference Vegetation Index) values can be calculated from satellite imagery (e.g. from freely downloadable Landsat or more recently Sentinel optical imagery).
   - **1.2.** Topographic Wetness Index (TWI) can be calculated from a digital elevation model.

2. **Model building**

- **2.1.** Assign base scores (possibly with local experts) for each ecosystem type. The types are to be scored according to their general ability to prevent a fast runoff (1 to 5 where 1 is the worst).
- **2.2.** Calculate NDVI as first modifying factor, to reflect differences due to the momentary condition of the vegetation.
  - **2.2.1.** Calculate the quartiles for each habitat type.
  - **2.2.2**. For each location, NDVI in the lowest quartile for that habitat category: -1; NDVI in the second quartile: -0.5, all the other areas 0.
- 2.3. Calculate TWI (Topographic Wetness Index) as 2nd modifying factor to include the effect of elevation.
  - **2.3.1.** Calculate the quartiles for TWI for the whole area.
  - **2.3.2.** For each location, TWI in the lowest quartile: -1; TWI in the second quartile: -0.5, all the other areas 0.
- **2.4.** Add the modifying factors to the base maps - the TWI factor is only used to differentiate between the more densely vegetated areas (only where the base score was 4 or 5).

Challenges

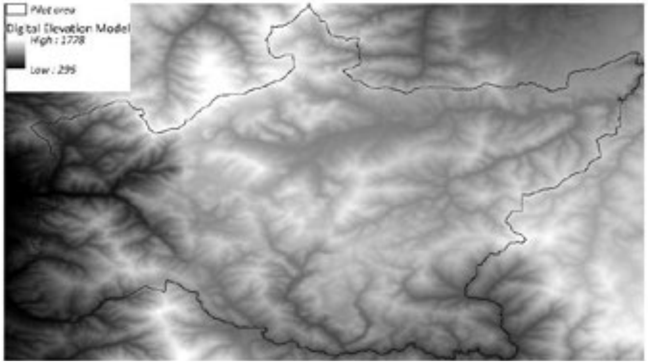
NDVI values measured at a given point in time depend on the momentary condition of the vegetation. Therefore, it is very important that the NDVI map and the ecosystem type map should correspond in time, and that the two maps overlap precisely (it is important to use the same coordinate system at the very least). If the quartiles calculated for the NDVI of the ecosystem types are wrong, then the results will be misleading.

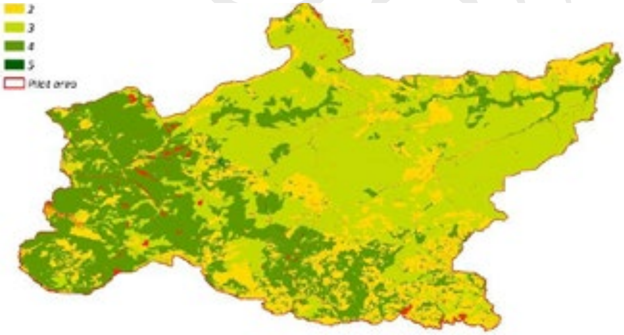
Quality check/Pros & cons

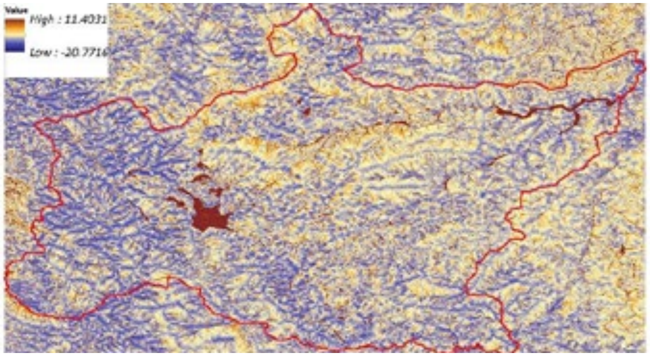
Quality check for water quality protection models would be very complicated even with field measurements - nitrate concentrations of different water bodies would have to be measured at several points, in order to reflect the filtration efficiency of an ecosystem unit and not merely water quality, and analysed in terms of the pollution sources and land cover within the catchments. Comparison with the results of modelling is also possible, however comparative analysis of the results of such models have shown that realistic modelling of nutrient export from large catchments is very difficult without measured data to calibrate the models (Hejzlar et al. 2009).

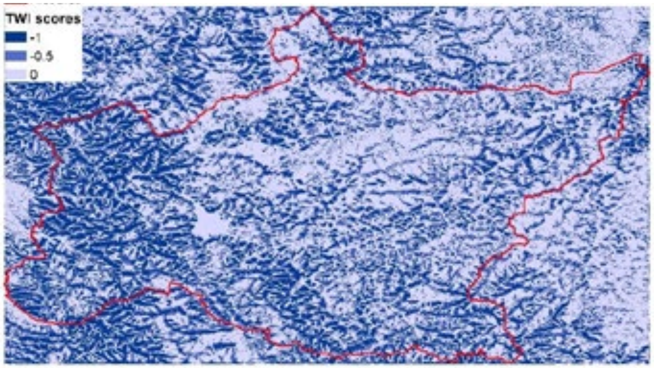
Example

The above process was used in the same way for most of the pilot areas in EcoKarst. We demonstrate the process on the example of Apuseni Nature Park. Base scores were assigned by local experts for each ecosystem type of the habitat type map. Scores were given according to the general ability of the ecosystem types to prevent a fast runoff (1 is the worst, e.g. barren surface, where the vegetation is not able to retain water for any amount of time; 5 is the best, where the dense vegetation is able to significantly reduce runoff). The maps were further elaborated by adding base scores.









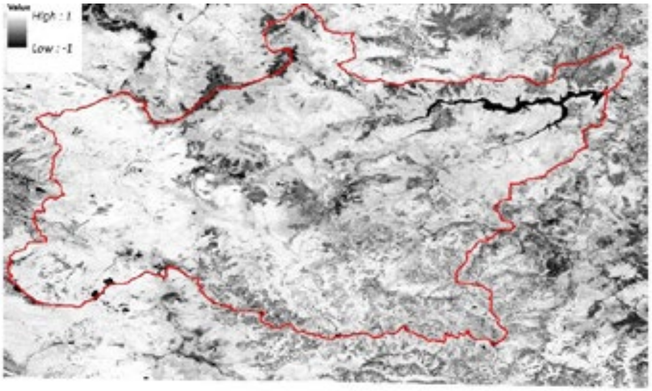


Figure 9: Water quality protection capacity - example of Apuseni Nature Park with the components (Digital Elevation Map, base score for habitats, Topographic Wetness Index TWI, NDVI and corresponding scoring).

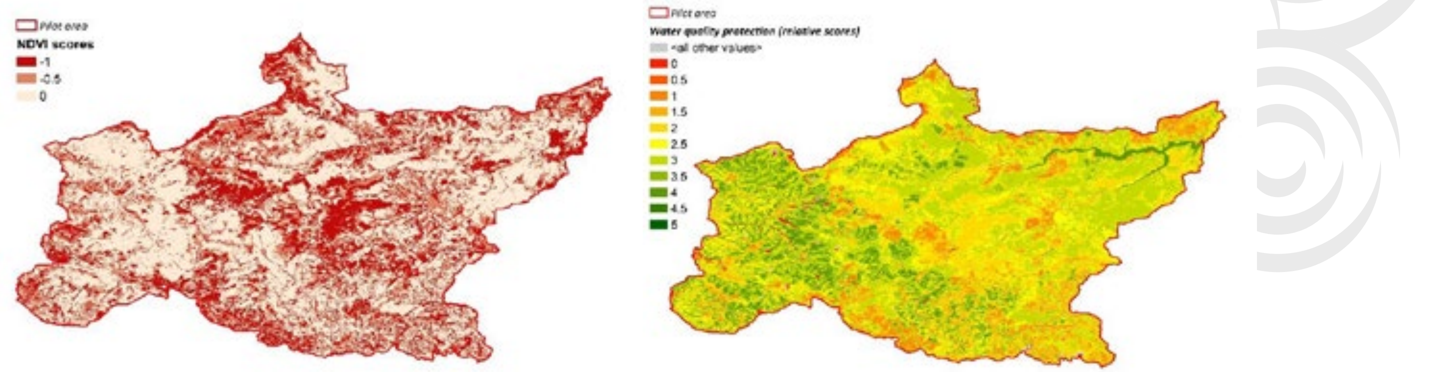


Figure 9: Water quality protection capacity - example of Apuseni Nature Park with the components (Digital Elevation Map, base score for habitats, Topographic Wetness Index TWI, NDVI and corresponding scoring).

NDVI reflects differences due to the momentary condition of the vegetation (e.g. severely disturbed or freshly cut forests with little cover will retain less water). Vegetation condition was considered bad when the values deviated from the typical values of their particular habitat type. It was calculated from Landsat satellite images from the summer (July/August) of the year 2017 using analysis-ready data from USGS. The quartiles of the NDVI values for all the ecosystem type categories were calculated using SAGA GIS on a multipart version of the ecosystem type map where each type represented one polygon. Then the values for each pixel on the NDVI map were compared to the lower quartile and median of the corresponding habitat type as described in the workflow above.

Topographic Wetness Index was calculated from a DEM, also using SAGA GIS. It was incorporated in order to include the effect of elevation, e.g. to note those areas where water runs off too quickly to get filtered. Soil type and depth would be ideally used for this but such data are often unavailable. TWI is related to these characteristics, therefore it was applied as a proxy. The TWI factor was only used to differentiate between the more densely vegetated areas (only where the base score was 4 or 5).

The values were added to the base score.

The resulting map (Figure 9) shows the relative potential of the ecosystems to retain water and to increase the retention of certain types of contaminants (e.g. nitrate) through increasing water residence time. As regulating services are often in trade-off with provisioning services (in this case with timber and firewood provision), such maps are apt for demonstrating and discussing the significance and multiple functions of ecosystems. If further information is added (e.g. the location of sinkholes and/or possible sources of pollution), it can be developed into a risk map.

Natural forage and fodder (hay)

Potential forage supply provided by the ecosystems through mowing or grazing. Cultivated or marketed roughage and grain feed are not included, as the amount of additional, anthropogenic input is dominant, while grazing on fallow land and stubble as well as plants spontaneously occurring on waysides and banks are included in this service.

As majority of places in Europe are suitable for forest growth (apart from high-mountainous regions, or some sites with edaphic limitations), most of the current grassland communities have evolved under anthropogenic disturbance regimes, and thus depend on the continuation of human activity. In the past, there were two major characteristic management schemes, the grazing of ruminants and, with the appearance of indoor livestock feeding, cutting grass for hay (mowing). The effects of these activities on the ecosystems depend on the intensity of use. Overuse in the past has led to reduction in infiltration capacity due to soil compaction), increased runoff and thus accelerated soil erosion. On the other hand the abandonment of grasslands has led to a progressive succession process and a growing proportion of woody plants which in the long run results in a significant reduction in plant diversity (Ljubičić et al. 2014) and finally, loss of grassland habitats. Due to a decreasing economic importance of traditional grazing and mowing there has been a tendency in some parts of Europe of grassland abandonment and reforestation in the last decades (see e.g. Biró et al. 2013). In some regions, both processes, overuse and abandonment take place parallelly. Natural grasslands however, have great significance in nature conservation, therefore sustainable grazing and mowing are important to maintain their high biological diversity. Grasslands are also important for the maintenance of other ecosystem services, like e.g. the provisioning of herbs or honey production and can also have cultural significance.

Data needs and data pre-processing

- ecosystem type map
- and further possibly - consult with experts concerning the exact data needs:
- biodiversity or other ecosystem condition indicator
- grazing intensity: create grazing pressure categories for pastures based on land use data in sites dominated by grazing, in pilots where either overgrazing or abandonment of pastures is an issue
- soil fertility: based on soil type, that is categorized with the help of expert(s) or additional literature sources according to the type's general suitability for plant growth

- elevation: classified from a digital elevation model according to the rules identified during the workshops
- steepness: derived from digital elevation model

Workflow

1. Set up the ES model (step 4 of the general workflow in Figure 4) in a mini-workshop organized with 2-4 local farmers.

1.1. Create a customized ecosystem type map optimized for hay provision (merge some habitat types and potentially divide others).

1.2. Score hay provision capacity along a relative scale (e.g. 1-5) for the customized ecosystem types.

1.3. identify rules modifying the scores in line with the expert judgement (step 5). Discuss with the experts which of the listed features might be of relevance for hay production:

- elevation
- soil fertility
- biodiversity
- grazing intensity
- slope steepness

and formulate their influence on the provisioning of hay in terms of relative scores with which they can be added to the map. For example: if the place is at an altitude higher than 1000 m a.s.l., hay production will be much lower, which we can represent on the relative scale with - 0.5 scores / -0.5% production. Find concrete rules that include:

- categories, to which they apply (e.g. >1000 m, "poor" soil fertility, "steep" (11-27°) slopes.)
- the assigned scores / changes in scores

1.4. Fix the scale: transform scores into biophysical units either of hay, or of the resulting benefit (e.g. hay, sheep/mutton, cattle/beef, milk) kg/ha/yr using literature data / statistical data / additional expert consultation.

2. create draft map based on the established model (step 7)

3. calibrate and if necessary, fine-tune the yield potentials calculated by the model with literature data / statistical data / additional expert consultation.

Challenges

It is important to delineate exactly the ES 'hay' from ES with higher anthropogenic input, like fodder from intensely managed/cultivated agricultural areas.
Separate scoring for pasture and mowing might be reasonable in some cases, however, the differentiation between potential ES (what can be mown/grazed from a site in theory) and the actual use poses a challenge here. If (many) anthropogenic features are included (e.g. roads, distance to villages) this might mislead the interpretation towards actual use.
Experience showed that for farmers, it is often easier to score exact places on a map, and not generalized ecosystem types.
Possible solution: the use of an ecosystem type map which is directly scored during the workshops, and a generalization of the scores to the related ecosystem types later on. It might be also more feasible to make an individual partial scoring, checking with the farmers one by one the provisioning capacity of the places they know. However, this gives additional importance to the generalization step.
Regarding the inclusion of biodiversity/ecosystem condition into the models: while there is some evidence, that cattle grazed extensively provides better quality products then when kept and fed intensively indoors, this is generally not what farmers reflect on during workshops. Therefore, the decision has to be made to adjust for this later on, adding biodiversity/condition data to the established set of rules. For many of the parks involved as pilot areas, this was an important point relating very much to their internal objectives of conservation and thus it was decided to be added to the maps of natural forage and fodder (zonation: Apuseni, biodiversity data: Bükk, NP Kalkalpen, Zumberak, or some other factor representing "naturalness" in the widest sense: Bijambare).

Quality check/Pros & cons

Show the farmers at your workshop the resulting ES map based on the compiled rules, look at some (new) places and discuss whether this corresponds to their experience.

Examples

In the case of the natural forage and hay service, most pilots followed the pre-designed method, but the factors and the scoring were different. We demonstrate two examples, one from Austria (Example 1, Figure 10) and one from Croatia (Example 2, Figure 11).

Example 1: National Park Kalkalpen

The rules and scores designed by the experts of NPK are as follows:

1) Habitat Type (base score): 1 = 1 ton 5 = 5 ton in hay production
2) Altitude: <600 m = +2; 600 – 900 m = +1; > 900 m = 0
3) Biodiversity: <74 species = 1; 74 – 148:2; 148 – 222: 3; 222 – 296 = 4; >296=5
4) Slope: 0-25° = 0; 25-35°=-1; >35°=-2

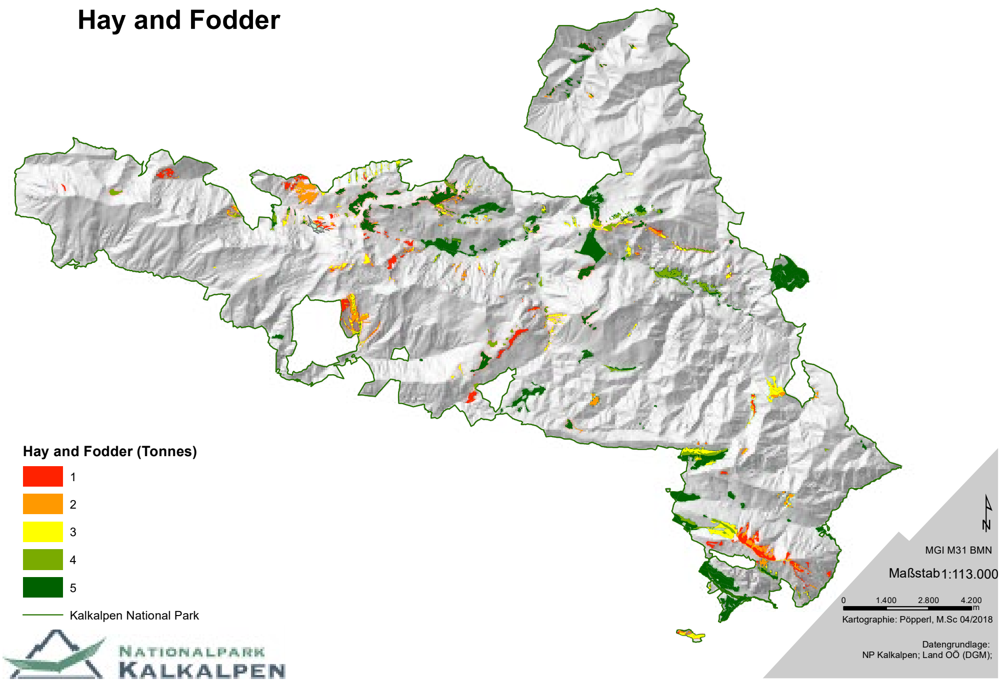


Figure 10: Hay and fodder provision potential map of Kalkalpen National Park (by F. Pöpperl).

Hay in Kalkalpen, is used in wellness treatements in addition to being used as fodder, which is an interesting feature.

Example 2: Nature Park Žumberak – Samoborsko gorje

Seven farmers from the area were visited personally as this was deemed the most effective way of collecting data. They were chosen so that different elevations and grassland types were represented in the sample. Since livestock breeding in the area exists almost entirely for personal / family needs, only hay potential was mapped. Bases scores were given from 1 (lowest potential for providing hay through mowing) to 5 (highest potential to provide hay through mowing). Additional rules were defined as follows:

Altitude (in meters)
0 – 549 = 2 (cca 3 – 4 T/ha)
550 – 700 = 1 (cca 2 -2,5 T/ha)
>700 = 0 (cca 1,5 T/ha)

Habitat naturalness described using vascular plant number per grassland:
1 – 9 plants = 0
10 – 19 plants = 1
20 – 39 = 2
> = 40 = 3

The summed scores are reclassified to a 1-5 scale.

The resulting maps show the potential of the different locations to provide natural forage and fodder for animals either quantitatively (Example 1) or relatively (Example 2). As often in the case of extended expert models (Tier 2), uncertainties of the results can be high due to the uncertainties of the input maps (habitats and soil) or the transformation to biophysical units.

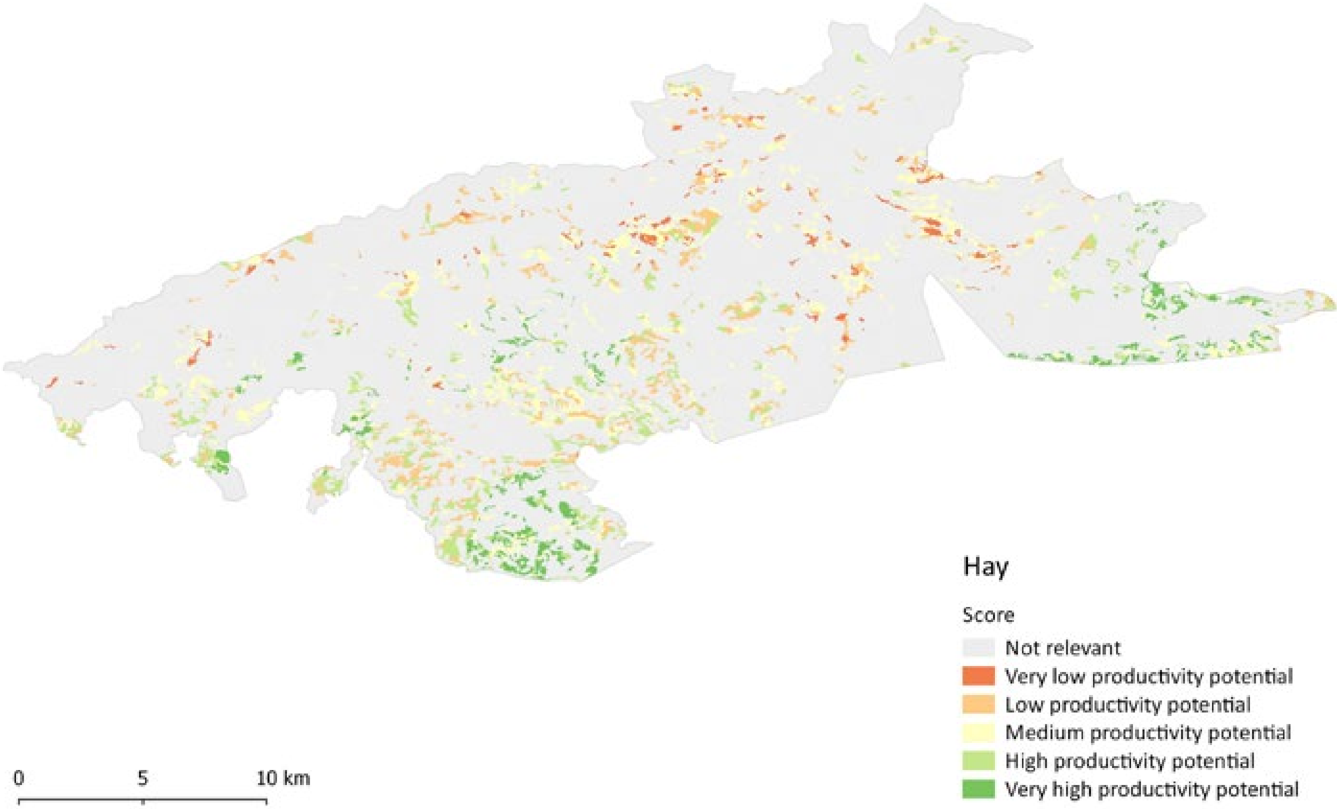


Figure 11: Hay and fodder provision potential map of Nature Park Žumberak – Samoborsko gorje (by Dubravka Kranjčević).

Touristic attractiveness of nature (tourism)

Ecological or landscape features and attributes that attract people for recreational or cultural activities

In addition to provisioning services that are easily understandable and the more obscure regulating services, which are vital for the balancing of natural procedures, there is also a wide and rather diffuse section of ES described as "cultural" - nonmaterial benefits people obtain from ecosystems as the Millennium Assessment (2005) defines them. Recreation and tourism are some of the better understandable and quantifiable cultural ecosystem services, which as such are often chosen in the assessments in order to represent this category. Hereby, "touristic attractiveness of nature" is very close to "recreation potential", generally relying on very similar attributes perceived by humans as relaxing, and adding directly to their mental well-being.

Data needs

- ecosystem type map, simplified, if needed and further possibly - consult with experts concerning the exact data needs:
- ecosystem condition e.g. the biodiversity-based condition map or other relevant indicator e.g. forest age / tree size
- landscape diversity: generated from ecosystem type map, e.g. using a moving window
- elevation and potentially steepness, generated from a digital elevation model
- distance from water
- (distance from) specific (natural) features of interest (e.g. typical sites for specific species, caves, rock formations, etc)
- man-made features with major contribution to attractiveness (e.g. hiking trails, biking routes, visitor centres, viewing towers)
- accessibility (not strictly nature-related but very relevant)

Workflow

1. Set up the ES model (step 4 of the general workflow in fig 4) in a mini-workshop with 2-4 local experts on tourism to set up the ES model:

1.1. Assign a base attractiveness score (e.g. 0, 1 or 2 in case of particularly attractive types) based on the experts' decision, but keep in mind that for this ES it is not the ET that are of decisive importance, but their composition (landscape heterogeneity), their relation to each other (e.g. a natural & easily accessible patch at a lake-side) and also to man-made features (roads, tracks, touristic info points, etc.), which can be introduced by rules based on selected modifying factors into the ES models (see next step). This is why we suggest generally lower base scores for ET - the experts may even choose to omit this step.

1.2. Define the rules for each modifying factor

- e.g. density or distance of interesting natural features, accessibility, distance from nearest settlements, naturalness, etc.) – There are no absolute numbers, as these are all relative scores;
- including the distance to which their influence reaches: how do their scores decrease with distance? - try to assess how far the effect of the named factor reaches, e.g. how far tourists can see/hear/feel the closeness of a waterbody, or, how much a viewpoint attracts visitors.

From point data such as "attractive points/features" heat maps can be generated based on the density of the points, representing attractivity in the form of a raster. This can be combined with additional attractivity features, such as proximity (distance) to water. It is also possible to calculate the length of hiking and biking tracks, and score the density categories and add this to the grid.

2. Create draft map based on the established model.

3. Verify the model with the experts and correct/update if necessary.

Challenges

Cultural ecosystem services are often difficult to assess due to their intangible nature and due to several methodological concerns. Distinction between potentials and actual use (or flows) is not trivial in their case (Burkhard et al. 2014). Man-made features are in a strict sense not services of nature. However, ES are always a co-production of man and nature, which is especially true for the ES "touristic attractiveness of nature" that simply does not exist without human contribution. With this in sight, try to choose those features, in which nature adds a relevant part to attractiveness. For a number of features relevant for touristic attractiveness, this might be hard to decide, nevertheless, a clear decision has to be made on where the line is drawn between the potential of a certain area and the actually used ES. Accessibility should especially be taken into account, which in most cases is also not nature's contribution. However, when the mapping aims to contribute to planning (as in our case) it should not be entirely left out, because it strongly defines where the tourists can actually go.

Possible solution: accessibility and all other human-made features which are hard to categorize, could be included as the last step and two maps should be generated - with and without. Making multiple maps with both adding and excluding accessibility can be highly valuable if tourist guidance systems need to be developed for protected areas. Vulnerable and highly protected areas as well as well-accessible areas and tracks can be planned accordingly.

For touristic attractiveness of nature, it is somewhat hard to define who is an expert. For one, no special occupation (like farmer or bee-keeper) is needed in order to have relevant knowledge of the distribution of this ES in the landscape. On the other hand, also with choosing experts, it might be hard to keep focus on those elements of this service that are specifically provided by nature and not by human made infrastructure. Thus, it might be better to inquire with national park rangers, guides etc., about the location of favoured places, rather than asking the persons officially working with tourists like hotel managers or touristic information services.
An additional challenge is that there are many specific forms of tourism. "Attractiveness" is different for a caver, a birder, a climber or an urban family on holiday with small children. It is practically impossible to construct a single model that would fit all. Also, experts from different fields may have conflicting views on the relative importance of the factors.

Possible solution: choose one or more target groups significant for the area of interest and concentrate on those aspects of attractiveness that are relevant to these. Try to invite experts with different backgrounds in order to reach consensus.

Quality check/Pros & cons

Show the experts in your workshop the resulting ES map based on the compiled rules, look at some (new) places and discuss whether this corresponds to their experience. Modify the model in line with the suggestions from the workshop. If data is available, an attempt can be made to compare relative scores of the maps with visitor numbers.

Examples

Here we present an example of Nature Park Žumberak – Samoborsko gorje. In this case, habitat types were used and base scores of naturalness assigned from 1 to 5, but only after aggregating some categories into one (EUNIS level2). Further rules and scores were defined thereafter and added to the base scores.

RULE 1 – attractions

Man-made features such as mountain huts, food, beverage and accommodation facilities were not included, nor were hiking and biking trails. However, after eliminating man-made features from the data, the number of points was too small to create a meaningful heat map. Instead, a 3 km buffer was drawn around each point and areas within buffer were given a score of +1, while outside buffer no score was given.

Attractions included:

- Mountain peaks
- Waterfalls
- Climbing spots (natural occurring steep rocks)
- Paragliding take-offs (natural occurring spots with needed air currents).

RULE 2 – streams

A 50-meter buffer zone was taken into account around the streams considering that roads run along 80% of the streams , so every stream is accessible by car, bike and/or foot. A score of +1 was assigned within the buffer zone, while outside no score was given.

RULE 3 – additionally protected areas

Some polygons of specific protected areas were added, including nature that most people find even more attractive than other parts of the park. The polygons received a score of +1 andeverything else 0.

After adding the modifying scores to the base scores, the results were rescaled to a 1-5 scale.

Two maps were prepared, the first including man-made features such as roads, accommodations, etc. and a later version (presented in Figure 12), which did not contain these. As the creators remarked, both maps highlighted more or less the same areas of the nature park as the most attractive, meaning that the inhabitants and local decision-makers were well aware of the most attractive features in the area and built features such as mountain huts, hiking trails etc. around or in the vicinity of the most attractive parts.

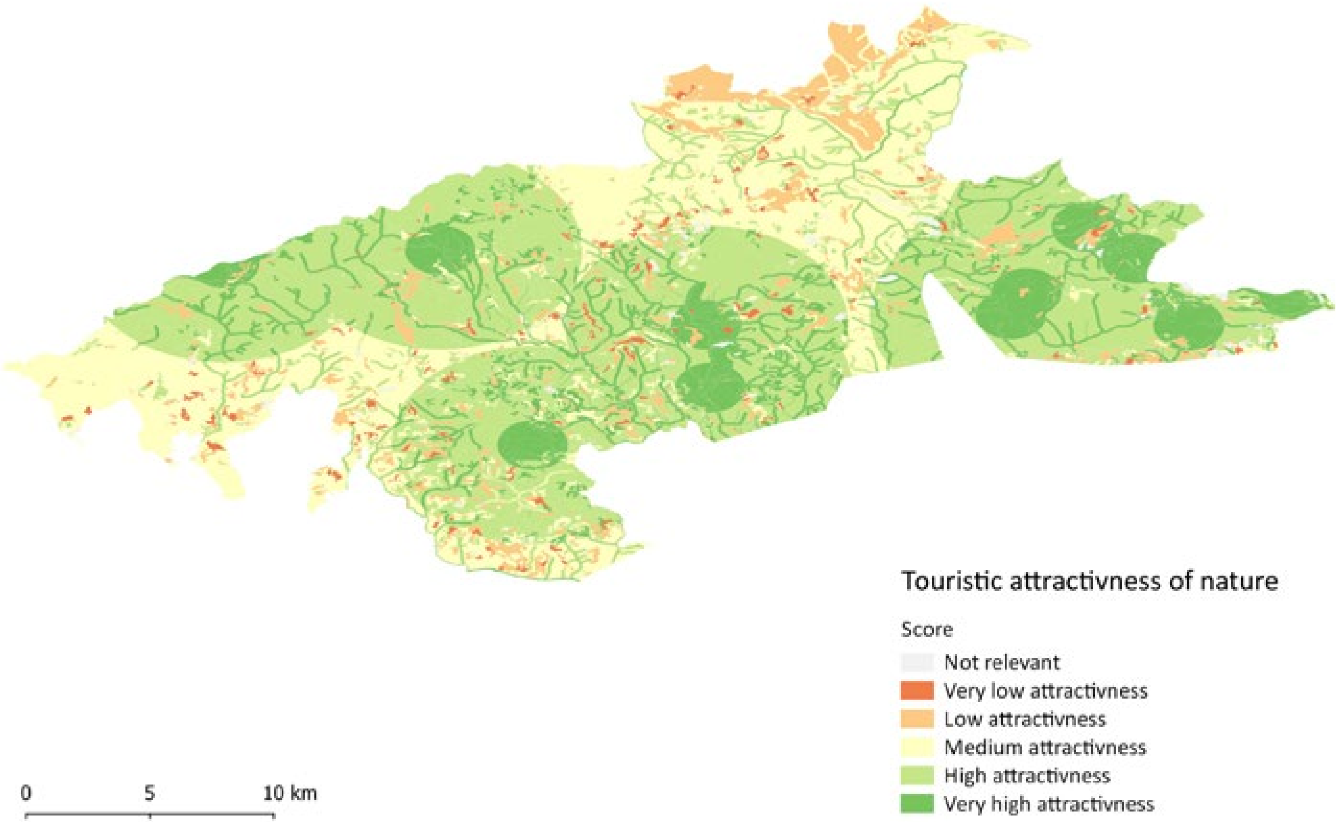


Figure 12: Touristic attractiveness of nature map of Nature Park Žumberak – Samoborsko gorje (by Dubravka Kranjčević).

Timber and firewood provisioning (timber)

Long-term timber and firewood provisioning potential of the habitat, assessed as a yearly average (m3/ha/year) considering the whole lifecycle.

The main forestry activity in today's Europe is focused on the production and harvesting of wood, even though the economic value of a wider variety of goods and services is receiving increased attention (EEA 2008). As wood is a conditionally renewable resource and, as such, subject to human overexploitation, the need to ensure the long-term sustainability of timber and firewood provision was recognized in Europe as early as the 17th century. The rise of forestry itself as a science (of sustainable yield) at the beginning of the 18th century was prompted by the vast demand of mining for timber (Agnoletti et al 2009). Drawing on the centuries of accumulated experience and research, the quantification of this ES can be based on a multitude of already existing data, methods and expert knowledge in most areas.
Forest inventories and/or management plans exist throughout Europe, and these usually contain information on the species composition, site characteristics, and the annual yield itself, usually in a spatially explicit form. However, the availability may depend on local legislation or on a good relationship with the data owner.

Timber and firewood provision Method 1 Expert knowledge on growth rates
This (Tier 1 or 2, depending on the experts) method is suggested for a situation where there is at least an ecosystem type map but no detailed forest inventory/management plan data are available for use.

Data needs

- Expert knowledge on growth rates, local site characteristics and approximate species composition of forest types
- Expert knowledge on modification factors, e.g:
    - elevation (digital elevation model)
    - steepness (digital elevation model)
    - soil fertility, based on soil type
    - potentially: map representing protected areas or areas of restricted use

Workflow

1. Data pre-processing; checking the available and missing input data.
2. Organize a mini-workshop with 2-4 local foresters, forest ecologists - mini-workshop with at least three local experts; foresters working as managers, and foresters or forest ecologist working in nature conservation (persons selected according to their experience and overview of the whole area): estimate the yield of the main tree species, scores, rules, scale fixing.
    - 2.1. Define the yield of the dominant tree species with the help of forestry production tables or expert knowledge.
    - 2.2. Define the yield of ecosystem types (either as a whole or on the basis of the share of the dominant tree species).
    - 2.3. If necessary, set the modification rules, e.g.:
        - elevation - yield declines on higher elevation;
        - steepness - yield declines with steepness;
        - soil type/depth - yield increases with soil depth.

3. Calibrate the fixed timber yield potentials with literature data / statistical data / additional expert consultation - individual consultations in the calibration phase: forestry expert to calibrate the yield potentials identified in the mini-workshop.
4. Create a draft map based on the scores and modifying rules.
5. Validate the draft map at the stakeholder workshop.
6. Modify the scores and rules according to the suggestions from the stakeholder workshop.

Challenges

In case of timber and firewood production, the sustainability consideration is especially important. Sustainability was originally (and in some places still is) considered only from the point of view of the yield ("the principle of sustained yield"), and did not necessarily extend to other functions of forests (Wiersum 1995). Although it is now widely recognized that such a narrow definition of sustainable forest management may result in a loss of biodiversity, the subsequent weakening of resilience and the loss of other functions and services, several hundred years of forest management has already caused a decline in forest biodiversity. There is no precise knowledge on how the extracted amount of wood affects biodiversity, and this way the sustainability and resilience of the forest stands but it is known that the biodiversity potential of a forest stand depends to a considerable extent on the way in which the trees are harvested (EEA 2008). The mode and type of forest management is the key factor determining sustainable forest use. The same amount of wood can be extracted in a sustainable yet a highly exploitative way. This should be taken into account while determining sustainable production.

With regard to the above, the capacity in the case of this particular ES should be defined in light of the condition maps and with clear sustainability criteria. There may be areas with no actual use whatsoever as a result of strict protection or some other consideration - in spite of some theoretical capacity of timber production. If there is any danger of increased management intensity as a result of mapping the potential, such areas can and should be masked.

Quality check/Pros & cons

The quality of the resulting maps can be checked with experts (either the same ones who made the rules, or others). As data on stock and increment usually exist, even if not available for the purpose of mapping, experts can give very precise estimates.

Examples

Here we include the example from Bükk National Park. As precise inventory data were not available for the mapping, an expert workshop was organised, where the workflow described above was followed. The most relevant local habitat types concerning the "Timber and firewood provision ES" (chosen by the experts) were as follows:

1. Beech forests,
2. Turkey oak / sessile oak forests,
3. Meso- and eutrophic oak, hornbeam, ash, sycamore, lime, elm and related forests,
4. Mixed riparian floodplain and gallery woodland, thermophilous deciduous forests,
5. Wooded pastures (with a tree layer overlying pasture),
6. Highly artificial broadleaved deciduous forestry plantations,
7. Highly artificial coniferous plantations.

The habitat type 'Meso- and eutrophic oak, hornbeam, ash, sycamore, lime, elm and related woodland' was split into (1) oak-hornbeam forests and (2) ash, sycamore, lime, elm and related woodland. This was possible, as the original habitat map was more detailed than the EUNIS map. The experts then assigned m3/ha/year data to selected habitat types (Table 3). They used expert knowledge on the volumes of wood usually removed at the various stages of management, including „cleaning", „pre-commercial thinning", „commercial thinning" and „final felling" to calculate average capacity of timber and firewood production (throughout the lifecycle of the different forest types, independent of the present age of the forest).

*Later estimation by the forestry experts.

	Overall provisioning capacity	Cutting age	Indicator
	(m^3/ha)	**(year)**	**(m^3/ha/year)**
Beech forests	475	110	**4.3**
Turkey oak – sessile oak forests	309	85	**3.6**
Oak-hornbeam forests	356	110	**3.2**
Ash, sycamore, lime, elm and related forests	356	110	**3.2**
Mixed riparian floodplain and gallery forests	356	73	**4.9**
Thermophilous deciduous forests	154	85	**1.8**
Acidophilous oak-dominated forests	154	85	**1.8**
Highly artificial coniferous plantations			**4.5***
Black locust plantations			**4.0***

Table 3: Expert estimations on overall capacity, typical cutting age (~lifecycle) and yearly average timber/firewood provisioning potential of the ecosystem type (m3/ha/year) throughout its lifecycle.

In order to further refine the map, the experts added two modifying factors: (1) Site quality (due to the lack of a soil type/depth map, it was approximated using the Topographic Wetness Index /TWI/(Table 5) and (2) Aspect (Table 4).

SW	SE	NW	NE
-8%	0	0	8%

Table 4: Modification of wood provisioning capacity due to aspect.

TWI<2	02.mar	03.maj	05.jun	TWI>6
-12%	-6%	0	6%	12%

Table 5: Modification due to site quality (with TWI as a proxy).

The resulting map (Figure 13) shows an estimated general annual timber and firewood producing potential (m3/hectare/year) of each location, regardless of the current age or condition of the stands. When looking at this map, it is important to keep in mind that this potential is purely theoretical. The amount of increment that can be used for wood production depends, among other things, on technical limitations (e.g. accessibility) and legal and ethical limitations (e.g. no cutting is allowed in forest reserves). In addition, this theoretical potential can be reduced significantly by abiotic and biotic damage (becoming more probable with the increasing frequency of extreme climate events). If used in planning, this map should be considered together with the maps of the ecosystem condition, water quality protection and carbon sequestration.

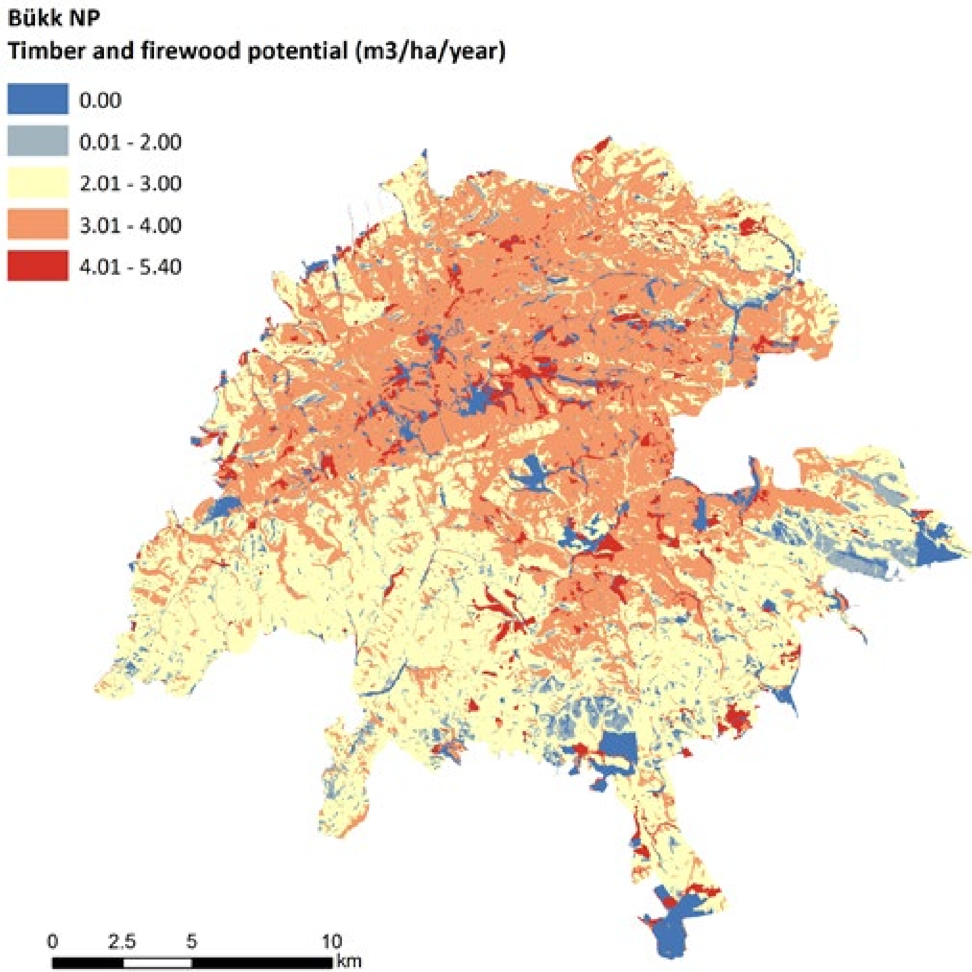


Figure 13: Timber and firewood potential of Bükk NP (m3/ha/year).

Timber and firewood provision
Method 2. Using data directly from forest inventories/management plans

As mentioned before, forest inventories and/or management plans exist throughout Europe to ensure the sustainability of yield. These usually contain information on the species composition, site characteristics, the stock and its annual increment as well, usually in a spatially explicit form (at the compartment or subcompartment level). As the form and content of such inventories and management plans varies, here we include only one example from Slovenia, where biodiversity requirements are also taken into account.

Example

The map of Notranjska Regional Park was created based on data from the Slovenian Forestry Service. As the objective was to use the map directly in creating action plans for the area, the definition of the map's would-be content was slightly modified. The map (Figure 14) corresponds to the quantities of timber that forest owners are allowed to extract in ten years according to the regional forest management plan 2011-2020. The average ratio of allowable cut in relation to the growing stock and increment were defined for a set of different forest developmental stages, which are provided according to the forest ecosystem types in the regional forest management plans for Postojna (2011-2020). These percentages were applied at the stand level considering that data on the growing stock for each stand of the specific development phase were available.. Since biodiversity requirements and other environmental and cultural forest functions are provided for in the Slovenian forest management plans, the allowable cut rarely exceeds 75 percent of increment.

The map reflects the quantities of timber that forest owners are allowed to extract in the period of ten years, according to the regional forest management plan 2011-2020. "Capacity", in this case, should be interpreted as the actual capacity allowed by the current condition (development stage) and aligned with the sustainability requirements (according to the definition of allowable cut).

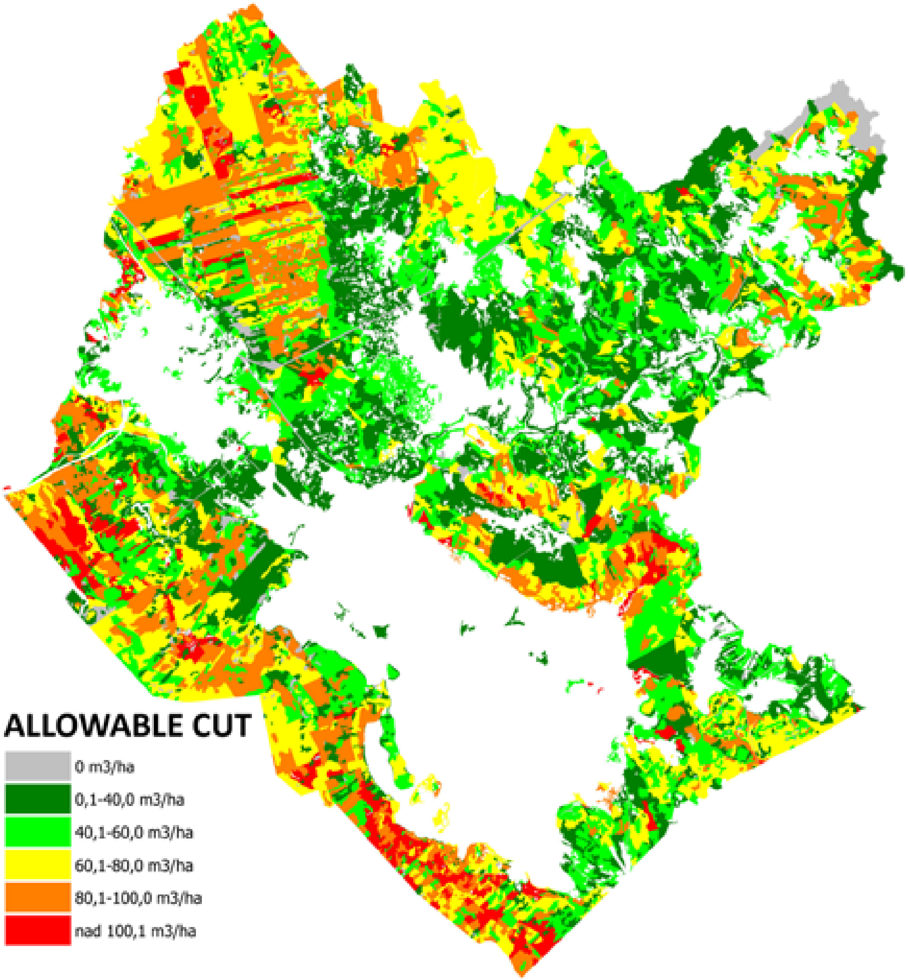


Figure 14: Allowable cut in Notranjska Regional Park according to Postojna regional forest management plan 2011-2020 (by Rok Pisek)

Medicinal herbs, mushrooms and forest fruits (berry)

Gathered mushrooms, fruits, berries and medicinal herbs provided spontaneously by the habitat. Cultivated plants and mushrooms are not included.

There are two possible approaches to work in this area: species-by-species approach, which assesses potential occurrence of species at a specific ET as well as their value, and the approach which combines species into groups. Grouping can be thematic (e.g. "medicinal herbs"), seemingly demanding less work. However, assessment is more difficult with grouping i as different species may have differing habitat requirements and very different value for people collecting them. If a number of species, or a selection of the most important species is assessed one by one, a more thorough picture can be given, allowing for a more detailed assessment. This latter method - looking at each single species' probable occurrence and value to gatherers can be also done in combination, i.e. in advance of the "group assessment" in order to elicit the different aspects (habitat requirements, values, seasonality, variability) that have to be accounted for. While this is somewhat more time-consuming, it might give a more consistent picture compared to starting immediately with a group-assessment.

Data needs & data pre-processing

ecosystem type map
and further possibly - consult with experts concerning the exact data needs:

- biodiversity or other ecosystem condition indicator
- grazing intensity: create grazing pressure categories for pastures based on land use data in sites dominated by grazing, in pilots where either overgrazing or abandonment of pastures is an issue
- forest use intensity/mode
- elevation: classified from a digital elevation model according to the rules identified during the workshops
- steepness, aspect (->insolation): derived from digital elevation model
- soil type: pH, texture - define if given soil types are typical acidic or alkaline and their type of texture (categories of soil map)
- humidity (Topographic Wetness Index): additional map of local regulations on harvesting (for masking out non-harvestable areas)
- accessibility and distance to acquisition points
- For implementing the species-specific alternative, select some of the more important species for your area.

Workflow

1. Set up the ES model (step 6 of the general workflow in fig 4) in a mini-workshop organized with 2-4 local gatherers (step 4 of the general workflow in fig 4):

1.1. Create a customized ecosystem type map (merge some habitat types and potentially divide others) to reflect only relevant habitat types for medicinal herbs, mushrooms, or other edible wild food you want to map OR for the specific species selected.

1.2. Score provisioning capacity for forest fruits, medicinal herbs and mushrooms OR specific species along a relative scale (1-5) for the customized ecosystem types.

1.3. Identify potential other rules modifying the scores, in line with the experts' opinion. Discuss with the experts which of the listed features might be of relevance:

- elevation
- soil type
- biodiversity
- grazing intensity

and formulate their influence on the provisioning of hay in terms of relative scores with which they can be added to the map. For example: acidic soils might be preferred by some mushroom species, add e.g. + 0.5 scores, or high grazing pressure might be detrimental to diversity of herbs and berries. Find concrete rules that include:

- o categories, to which they apply (e.g. >1000 m, "poor" soil fertility, "steep" (11-27°) slopes.)
- o the assigned scores / changes in scores.

1.4. If possible, fix the scale in line with the additional expert consultation/ literature data / statistical data: transform scores into biophysical units (e.g. kg/ha) to serve as basis for transforming capacity scores into benefit volumes (e.g. hay, sheep/mutton, cattle/beef, milk) /ha/yr.
If assessing species by species, note down their relative importance (reflecting length of harvest, frequency, value to gatherers).

- Check with gatherers whether any important species are missing.

To represent the group (e.g. "medicinal herbs"), combine the species-assessments weighting them with their value to gatherers and frequency of occurrence.

2. Create a draft map based on the scores and modifying rules.

Challenges

With such a diverse ES it is almost impossible to convert a relative capacity score to any biophysical quantity. This is not only due to the variability of this ES but more often to the lack of exact knowledge on yields. Rarely are species' environmental requirements so well researched, that detailed models can be compiled (but see for example Turtiainen et al. 2011 for Finnish forest fruits, Santos-Silva et al. 2011 for Portuguese mushrooms). Usually, it is the expert knowledge that is the best source for estimating provisioning of this ES. Nevertheless, especially when forest fruits, medicinal herbs, or mushrooms are collected locally in great amounts, a sensible regulation, based on the real potential of the ET to grow these species would be desirable, as well as the knowledge of how much can be extracted in the long-term without harm.

Quality check/Pros & cons

Show the gatherers of your workshop the resulting ES map based on the compiled rules, look at some places and discuss whether this corresponds to their experience. Modify the model according to suggestions from the stakeholder workshop.

Examples

The possibility to assess a whole group of wild food/herbs species was implemented only for mushrooms. While rather diverse, mushrooms seem to be nevertheless more uniform in their requirements towards environmental features. One park (Zumberak) included elevation, forest age, and steepness and aspect into their capacity maps (together with a buffer around roads) and modified the base scores with these features. Another example provided by Apuseni National Park is selection of three most important mushroom species in the region (Boletus edulis, Cantharellus cibarius and Armillaria mellea) and determination of modifying factors for each species for a weighted assessment, with Boletus counting double. Base scores were assessed for all three species separately, while altitude was also important.

For assessing wild fruits, NP Apuseni created two groups (the first group were blueberries (Vaccinium myrtillus) and cranberries (Vaccinium vitis-idea) and the second group were raspberries (Rubus idaeus) and blackberries (Rubus fruticosus) within forest fruits

based on the habitat requirements, which largely differ. For the final map representation only the best habitats were presented for each group. The economic importance of the two groups was taken into consideration for the combined final representation.
Two groups were assessed with regards to medicinal herbs, each represented by one major species collected there: grasslands (associated

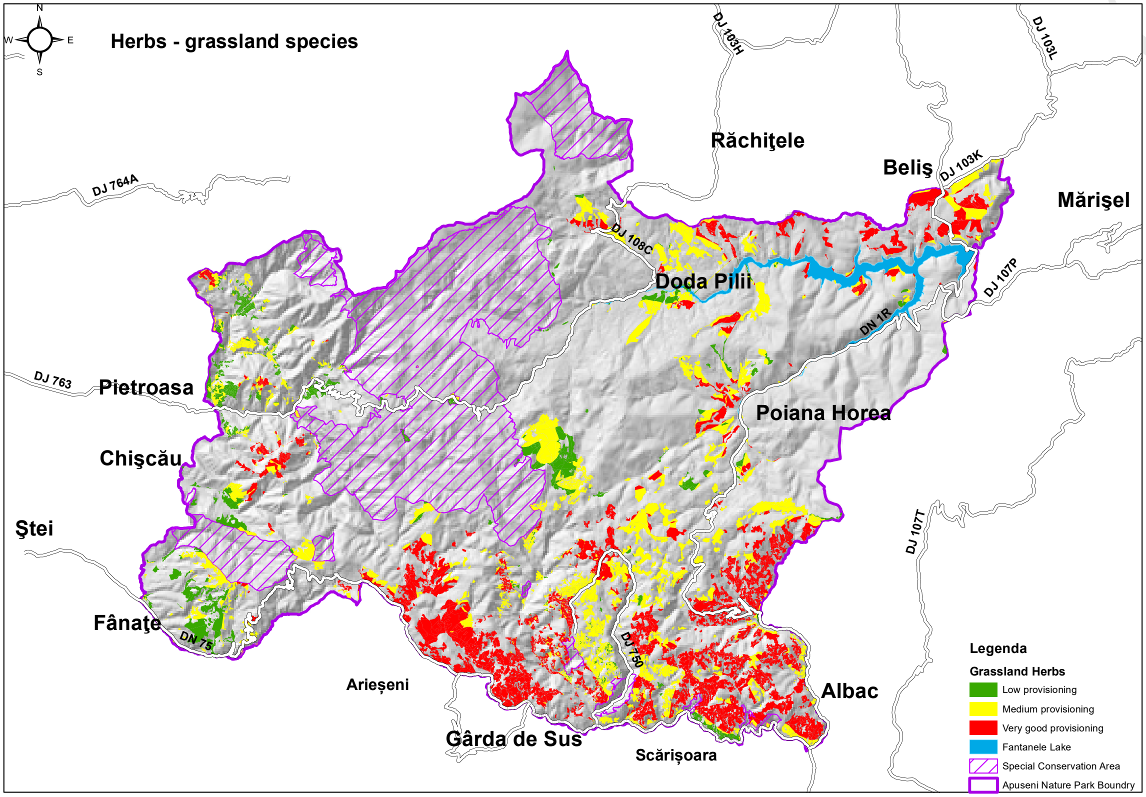


Figure 15: Capacity map of the grassland related herb species for Apuseni National Park (map by Anghel Drasovean). Areas where collecting is not allowed are marked with purple stripes.

with Arnica) (Figure 15), forests (associated with Allium ursinum) (Figure 16) and riparian sites (associated with Sambucus Nigra). Herbs and mushrooms gathered in the wild constitute an important source for the local people, in terms of food as well as additional, seasonal income. It is important to represent supply capacities only in available areas when mapping, and to formulate regulation in a way that medicinal herbs and food from the wild can be collected in a sustainable way.

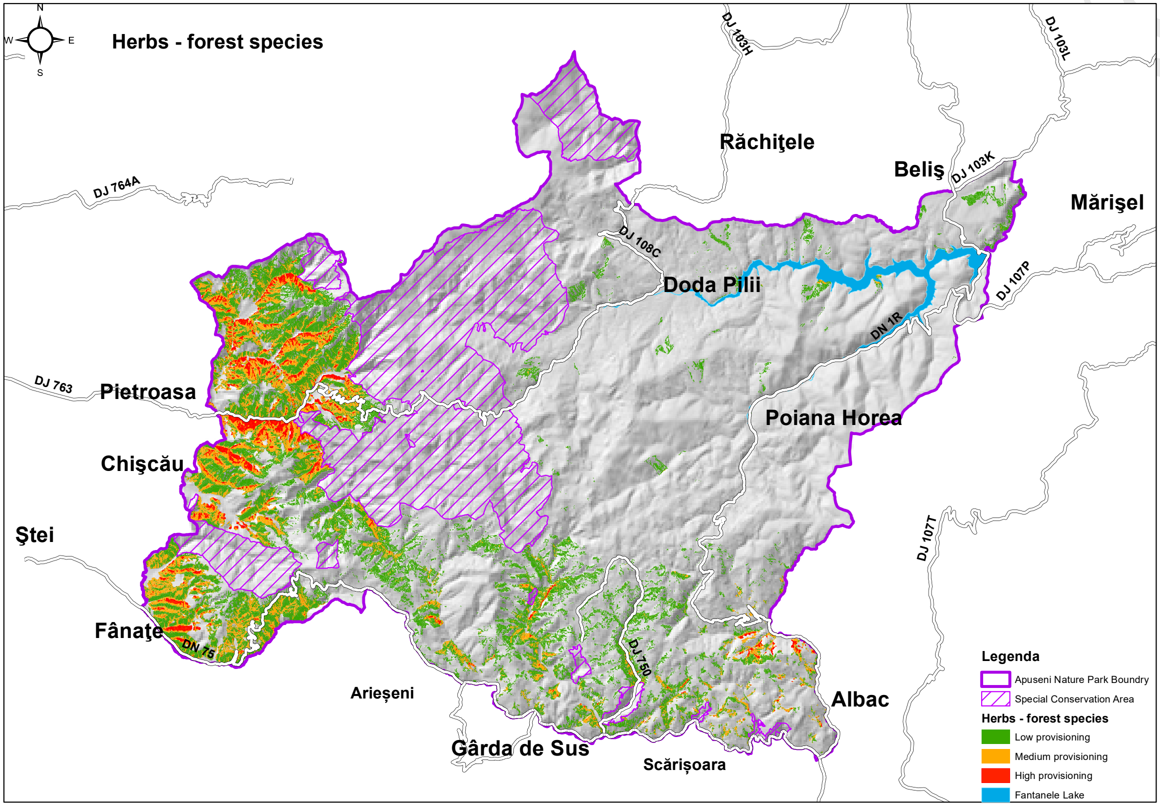


Figure 16: Capacity map of the forest related herb species in Apuseni National Park (map by Anghel Drasovean). Areas where collecting is not allowed are marked with purple stripes.

Carbon sequestration

Definition: Sequestration of atmospheric carbon by the living biomass, as contribution to global climate mitigation. Carbon storage is not included.

Terrestrial ecosystems regulate climate through both biogeochemical (greenhouse-gas regulation) and biophysical (regulation of water and energy) mechanisms (Teixeira et al 2012). Due to the imminent danger of global climate change, climate regulation through carbon sequestration is currently one of the most widely acknowledged regulating services. Even though the contribution of a small area in the reduction of atmospheric CO2, g counteracting global climate change, may be perceived as negligible, the maps depicting regulating service potentials are useful reminders of the significance of this vital ecosystem service and can stimulate discussion on the multiple function and trade-offs of ES.

Carbon sequestration – Method 1

The methodology[1] provided by the Intergovernmental Panel on Climate Change (IPCC) on the assessment of climate relevant gases (Egglestone et al. 2006) can be consulted for a large-scale assessment., oHere we have singled out some of its features to serve as quick guidance for the assessment of CO2 sequestration.

The main component of the IPCC assessment is focused on the land-use changes, which will not be considered here because our assessments is focused at one given point in time. The assessment does not cover the soil carbon, only the below-ground C that is included in woody biomass (roots). Applying the land use categories as they are, we can say that the change in woody biomass is predominantly related to the changes in the the CO2 balance regionally. Apart from the forests - for which we provide also a more detailed modelling approach under Method 2 - these are mainly young woody / scrub covered areas, as well as other tree-plantations, some of which are categorized by the IPCC methodology as cropland, e.g. vineyards and orchards.

For a Tier 1 model, in many cases default values given by the IPCC guidance can be used. If you have more detailed data, Method 2 might be more appropriate for forests.

1 https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/1_Volume1/V1_1_Ch1_Introduction.pdf

Data needs & pre-processing

1. Look up & download the national Greenhouse gas inventory report of your country.
2. Ecosystem type map - match your ecosystem types to the ones used by IPCC (International Panel on Climate Change), e.g. as in Table 6.
3. Look for national data on above-ground woody biomass growth rates (annual wood stock increment) for forests or an approximate tree species composition for each forest type and input data for a carbon sequestration model:
   - **3.1.** Yield tables (containing the typical wood stock increment values) for the main tree species – groups.
   - **3.2.** Wood density of different tree species (e.g. from the Wood Density Database such as Donegan at al. 2014) or see Table 7.

"own" categories /example	IPCC category	IPCC code
settlement	Settlements: Construction + Roads/Railways	5E
intensive agricultural	Cropland: Arable	5B
extensive agricultural	Cropland: Arable	5B
pasture	Grassland: Pastures + Hayfields;	5C
hay meadow	Grassland: Pastures + Hayfields;	5C
encroached grassland	Cropland: revegetated	5B
wood pasture	Grassland: Pastures + Hayfields;	5C
orchard	Cropland: Vineyards + Orchards;	5B
tree group	Forestland	5A
pine and spruce forest	Forestland	5A
robinia forest	Forestland	5A
broad-leaved forest	Forestland	5A
water	Wetlands: Waters/ponds;	5D

Table 6: example of a correspondence table for "own" categories used during the ES-mapping and the categories used by IPCC

Workflow

The Gain-loss method calculates all gains, that is all newly developed biomass, and subtracts all loss of bound C, e.g. due to logging. Data on biomass stocks, increments, harvests, etc., initially can be in units of dry matter that need to be converted to tonnes of carbon for all subsequent calculations.

For forests:

Gain-calculation according to the main species and species groups, based on the average annual biomass increment above and below-ground (with average annual increment of the growing stock, root:shoot ratio, wood density and C fraction in biomass).

Look for national data on above-ground woody biomass growth rates. If you can use country specific data for the annual estimation of C stock increment, that meets Tier 2 methodological level. However, if no detailed data is available, use the given default values by IPCC for temperate climate regions:

TABLE 5.1
DEFAULT COEFFICIENTS FOR ABOVE-GROUND WOODY BIOMASS AND HARVEST CYCLES IN CROPPING SYSTEMS CONTAINING PERENNIAL SPECIES

Climate region	Above-ground biomass carbon stock at harvest (tonnes C ha^{-1})	Harvest /Maturity cycle (yr)	Biomass accumulation rate (G) (tonnes C ha^{-1} yr^{-1})	Biomass carbon loss (L) (tonnes C ha^{-1} yr^{-1})	Error range[1]
Temperate (all moisture regimes)	63	30	2.1	63	± 75%
Tropical, dry	9	5	1.8	9	± 75%
Tropical, moist	21	8	2.6	21	± 75%
Tropical, wet	50	5	10.0	50	± 75%

Note: Values are derived from the literature survey and synthesis published by Schroeder (1994).
[1] Represents a nominal estimate of error, equivalent to two times standard deviation, as a percentage of the mean.

The average annual increment in biomass (GTOTAL) is calculated as

$G_{Total} = Iv * D* (1+R)$ (GPG LULUCF 2003)
with
G_{total}: average annual biomass increment above and belowground, tonnes d.m. ha-1yr-1;
Iv =average annual **increment** of the growing stock on species/group of species, m3ha-1yr-1;
R= **root-to-shoot ratio** appropriate to increments, dimensionless;
D = basic **wood density,** tonnes d.m. m-3.

For wood density (D), country specific values are calculated in studies, see Table 7 for example. For categories not specified, annua average increment of 5.6 m3 / ha / year is suggested.

Groups	I_v ($m^3ha^{-1}yr^{-1}$)	D (tonnes d.m. m^{-3})	R+1	G_{total} (tonnes d.m. $ha^{-1}yr^{-1}$)	G_w (aboveground) (tonnes d.m. $ha^{-1}yr^{-1}$)
Coniferous	06.maj	0.4	1.215	3.159	02.jun
Beech	05.maj	0.655	1.165	4.197	3.603
Oaks	04.jul	0.645	jan.85	5.608	3.032
Hardwood	04.jul	0.6	1.165	3.285	feb.82
Softwood	07.apr	0.41	1.165	3.535	3.034
else	05.jun	0.542	jan.29	3.915	3.035

Table 7: example of calculated wood density values

Root-to-shoot ratios (R) are country specific established as country wide average on group of species/major species.
Loss: Logging volume calculated for whole area for each species/group
The annual carbon loss due to wood harvesting is calculated as

$L_{fellings} = H * D* (R+1) * CF$
with
$L_{fellings}$ = annual carbon loss due to wood harvesting [tC/year]
L other losses= other annual carbon losses, due to illegal logging [tC/year].
H = annual volume of wood extracted [m3/year].
R= root-to-shoot ratio appropriate to increments, dimensionless;
D = basic wood density, tonnes d.m. m-3.
C fraction (CF) is assumed to be 0.5 of the dry biomass according to the IPCC GPG LULUCF (2003).

For Cropland:

Most of the IPCC Cropland category is represented by annual crops that do not have any longterm C-sequestration potential. Relevant categories are so-called woody crops - orchards, vineyards - and revegetated areas.
For the **woody crops** (orchards), the IPCC default emission factors for biomass accumulation can be used, based on these average values for gain and loss:

- annual biomass accumulation rate of 2.1 tC ha-1 yr-1 and
- C stock in biomass loss of 63 tC / ha.

For **revegetated areas,** covering encroached grasslands and shrublands (more or less comparable to EUNIS category G5.6 : Early-stage natural and semi-natural woodlands and regrowth) suggested average values for gain and loss can be used.
IPCC default emission factors are as follows:
Average C stock change in biomass in such patches is 2.09 tC/ha/yr, while annual C loss on these lands is around 1GgCO2/year.
The Tier 1 method assumes that the dead wood and litter stocks are not present in Cropland or are at equilibrium as in agroforestry systems and orchards. Hence, there is no need to estimate the carbon stock changes for these pools.

For grassland:

For land remaining under the same use, it was assumed that there were no changes in the C stocks of any pool (neither aboveground, nor belowground).

Challenges

See at Method 2 - CO2Fix

Quality check/Pros & cons

See at Method 2 - CO2Fix

Carbon sequestration – Method 2 CO2Fix

As most of the pilot areas in EcoKarst have a significant forest cover, we decided to include another method, which focuses on the carbon sequestration of the forests.

Data needs

4. ecosystem type map

5. annual wood stock increment in the forests (e.g. at the compartment or sub-compartment level) or an approximate tree species composition for each forest type and input data for a carbon sequestration model (in our example, CO2Fix, see Masera et al. 2003):

- **5.1.** yield tables (containing the typical wood stock increment values) for the main tree species
- **5.2.** wood density of different tree species (e.g. from the Wood Density Database[2])
- **5.3.** annual turnover rates
- **5.4.** basic climatological data (monthly mean temperatures, sum of precipitation in the vegetation period)
- **5.5.** relative growth of the other biomass compartments (e.g. branches, litter) - from the literature

Workflow

If data on the annual wood stock increment of forests is available, carbon sequestration of the living biomass can be directly calculated from that using wood density and the ratio of carbon to biomass for each tree species. Here we describe an example of a workflow for forests when such data are is not directly available.

1. Define the "typical" species composition and site quality of each forest type.

2. Look up the yield tables of each major tree species according to the previously defined site quality classes and enter them into the CO2Fix model along with the other required data.

3. Run the model for the specified period of time.

4. Add up the carbon sequestered by each species in each ecosystem type, weighting them according to their proportion.

5. Map the results using the ecosystem type map.

2 http://db.worldagroforestry.org/wd

Challenges

In both methods we knowingly excluded the assessment of carbon stock due to the lack of data - despite the fact that the higher climate regulation values of natural ecosystems mostly come from carbon stocks accumulated over a long time. As already mentioned at the timber and firewood provision ES, there are usually sufficient data (or expert knowledge) on forest growth, which also helps in estimating the amount of carbon sequestered in the above-ground biomass. But much of the carbon is not stored in the living above-ground biomass, but also in the deadwood, roots and the soil (Harmon et al 2001) of which there's usually little information. Therefore, it is important to keep in mind that if only sequestration is considered, we get a biased picture regarding the actual ''CO2-value'' of ecosystems, and specifically the balance between regulating and provisioning ES.
Another challenge is that there is less information available on non-forest ecosystem types.

Quality check/Pros & cons

The amount of carbon stored in different parts of plants or the soil can be measured, which means that the results can be validated.. It is also possible to look up the many attempts in the scientific literatureaiming to validate different models and verify the results.

Examples

It is generally agreed that of terrestrial ecosystems, forests provide the highest climate regulation services. In Bükk NP, forests cover most of the pilot area. The capacity of other ecosystem types to sequester carbon can be considered negligible compared to that of the forests, so this ES was mapped only for the forests. In order to estimate their carbon sequestration capacity, the CO2Fix model (v. 3.2), was used (Masera et al. 2003). It quantifies the carbon stocks and fluxes in the forest biomass, the soil organic matter and the wood products chain. These are estimated with a time-step of one year using the 'cohort' as a unit, where each cohort is defined as a group of individual trees assumed to exhibit similar growth. Parameterisation of the model was the same as described in Tanács et al. (2016). The total carbon content of the system was obtained by adding up the modelled amount of live biomass and soil carbon content at the end of a period of 100 years. As we aimed to map the potential, we did not consider management activity or the amount of carbon stored in wood products. The annual yield of stem wood was derived from the national forest yield tables. These are available for the commercially significant four tree species of the Bükk area (Fagus sylvatica, Carpinus betulus, Quercus petraea s.l., Q. cerris). As there was no direct information on the precise tree species composition of the habitat patches, a 'typical' tree species composition was drafted for the more important EUNIS level 3 forest habitat types (e.g. beech forests were supposed to have typically 90% beech trees and 10% hornbeam). The model was run for a period of 100 years for each species and then the results weighted with the proportion of each in each ecosystem type before being added up. See the result map in Figure 17.

Carbon sequestration potential maps show the amount of carbon stored in a particular location within a specified period of time. In the case of Bükk NP, the result map shows the estimated amount of C (t/ha) potentially stored in the forests (in the biomass and the soil) in a period of 100 years if there is no major disturbance. Although the methods of mapping differ, the patterns are very similar to those of the timber and firewood production potential of the same area, as the forests having the highest potential for the one also have the highest potential for the other.

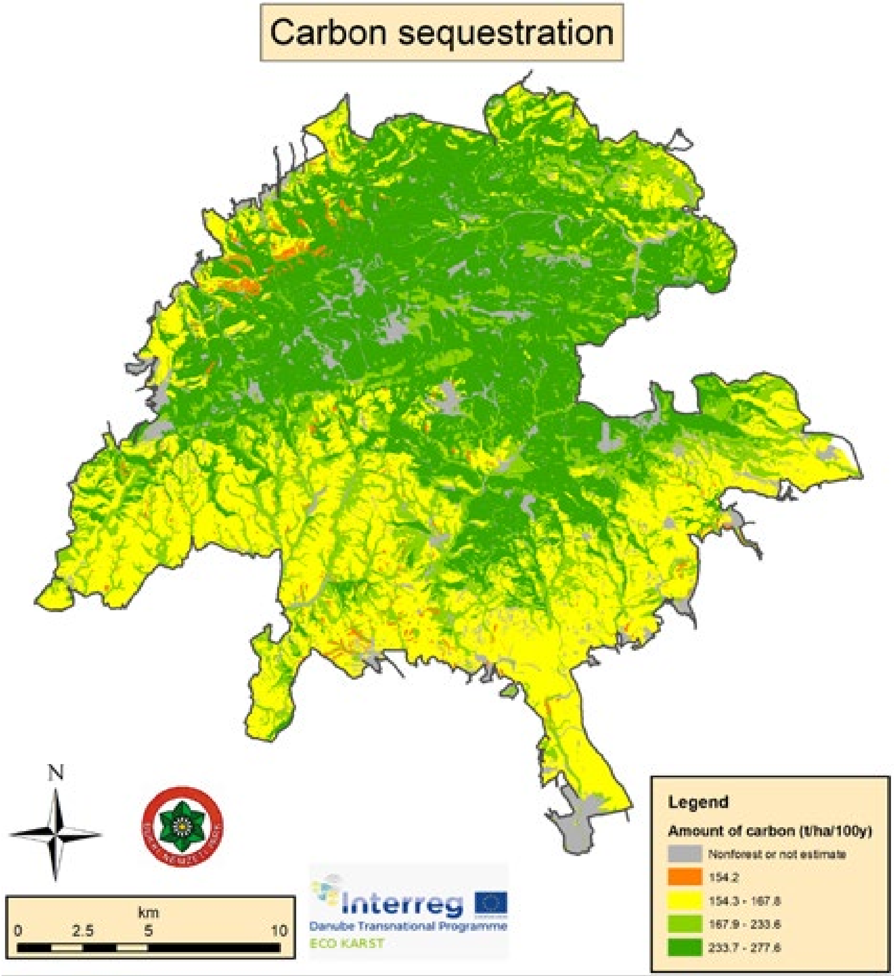


Figure 17: Carbon sequestration capacity of the forests in Bükk NP (by András Schmotzer)

Agricultural crops

Definition: sustainable provisioning of agricultural crops

Data needs

- soil fertility (based on soil type, soil organic C content, soil depth) or (national-level) map on the agricultural value of a given land
- precipitation map (not necessary in small areas as there won't be any big differences)
- landscape heterogeneity (mean size of agricultural parcels) and/or percentage of enriching structures (representing condition)
- elevation (digital elevation model)
- aspect (digital elevation model)
- steepness (digital elevation model)

Workflow

1. Define categories of soil fertility based on the soil types of the soil map.
2. Organize a mini-workshop with 2-4 local farmers to set up the potential crop yield model
3. Identify potential rules for the potential crop yield model according to the expert judgement:
  - **3.1.** soil fertility (example: low soil fertility: -0.5 high soil fertility: +0.5)
  - **3.2.** elevation (example: >500 m: -0.5 score)
  - **3.3.** slope steepness (example: steep (11-27°): -0.5 very steep (>27°): -1)
  - **3.4.** ecosystem condition/landscape heterogeneity (example: lowest tertile: -1, upper tertile: +1).

4. Calibrate: transform scores into biophysical values (kg/ha/yr) which serve as basis for transforming capacity scores into benefit volumes (with literature data / statistical data / additional expert consultation).
5. Create a draft map based on the established model.
6. Validate the draft map on the stakeholder workshop, modify rules if needed.

Challenges

It is important to restrict the assessment to the potential based on the ecosystem itself, excluding human inputs.

Quality check/Pros & cons

Validation is possible either with the help of experts or farmers. The resulting maps can be compared to different crop yield maps, if such maps are available.

Examples

Nature Park Zumberak defined within the ecosystem service "agricultural crop production" the growth of fruit in high-stem orchards, i.e. the potential of habitat type for growing high-stem fruit trees. For this they used apart from the base score for the habitat types additional rules for soil depth, elevation, aspect. Even though there are serious concerns about the extent to which suitable areas should be utilized, current regulations are not included into the model (see Interpretation of results).
This map (Figure 18) should be interpreted with care, because not all areas suitable for agricultural use in theory should be utilized for those purposes. Many grassland habitats would make good arable lands. However, turning grasslands into orchards or arable land would cause legal problems associated with the land use change and violation of the obligation to preserve e.g. Natura2000 grasslands.

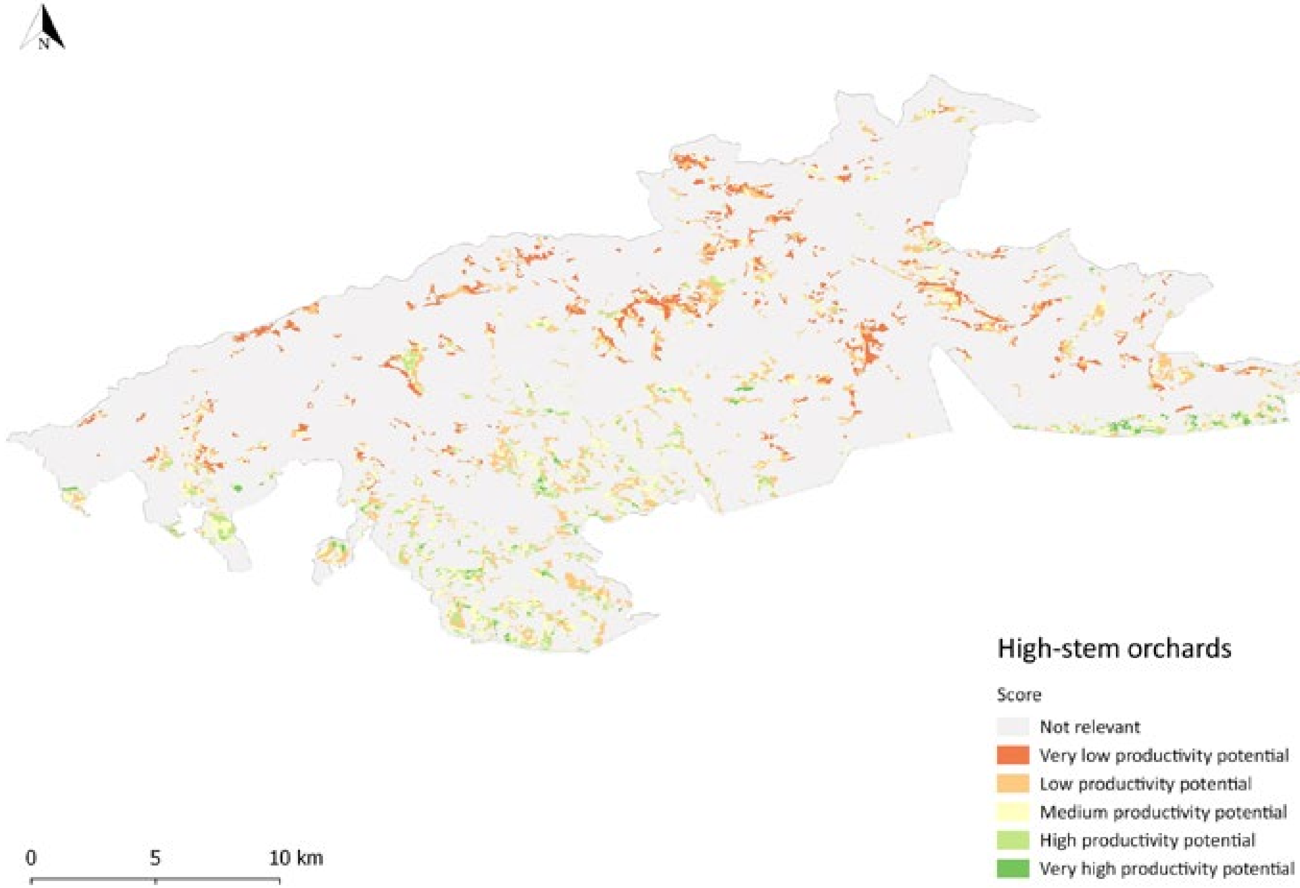


Figure 18: Capacity map of agricultural use (here: high-stem orchards) in Nature Park Žumberak - Samoborsko gorje (by Dubravka Kranjčević).

Provision of nectar and pollen for honeybees (honey)

Definition: Potential of the habitat to supply nectar and pollen for honeybees and thus contribute to honey production.

Honeybees contribute to the supply of various ecosystem services to people. Provision of honey is most notable, but certainly not the only one. Besides honey, there is the important regulating service of pollination, which has gained global attention due to its vulnerability to intensive farming and, at the same time, agriculture's dependence on it, with 90% of crops partly or exclusively insect pollinated. Mindful of the spectrum of potential services mediated by honeybees, in this guide we focus on the honey (nectar and pollen) provisioning capacity because of its relative straightforward link to ecosystems and economy. Honey is an important source of rural income in South East Europe and some countries export large quantities of it.. Preferring a diverse diet, honeybees forage nectar and pollen of numerous cultivated and wild flowering plants about which beekeepers have extensive knowledge and field-based experience. Indicators of abundance of floral resources may be helpful in describing an area's potential to support pollination. In the following chapters two alternative methods are described for mapping honey provision.
Provision of nectar and pollen for honeybees (honey) Method 1. Map based on ecosystem types + environmental variables

Data needs

- ecosystem type map

  and further possibly - consult with experts concerning the exact data needs:
- ecosystem condition map
- map of anthropogenic influence / land use intensity
- digital elevation map
- soil type map

Workflow

1. Data pre-processing:

- **1.1.** Create a customized ecosystem type map optimized for honey provision (merge some habitat types and potentially divide others).
- **1.2.** Create categories of anthropogenic pressure based on the land use data (e.g. overgrazing/land abandonment of grasslands based on livestock number per area).
- **1.3.** Simplify the digital elevation map by creating relevant altitude range categories.
- **1.4.** Create soil fertility map by defining categories of soil fertility (e.g. low - medium - high) and assigning the categories to soil types.

2. Organize a mini-workshop with 2-4 local beekeepers to set up the ES model:

- **2.1.** Score honey provision capacity of the simplified habitat types along a relative scale (1-5).
- **2.2.** Identify rules to incorporate additional variables (choice based on expert decision):
  - ecosystem condition (naturalness or biodiversity)
  - anthropogenic pressure
  - elevation range categories
  - exposition of slopes (based on digital elevation map)
  - soil fertility categories.

3. Optional: fix the scale by assigning measurement units of potential (average) yield (kg/ha/yr honey) to the scores. The ordinal-scale scores from the rule-based model can be linearly transformed into real biophysical values based on a number of fitting points within the area. The fitting points represent the data on the actual use from the specific locations, based on the consultations with beekeepers.

4. Create a draft map based on the established model.

5. Validate the model with additional expert consultation.

6. Modify the scores and rules in line with the feedback from the experts.

Challenges

Differentiation between stationary and migratory beekeeping: scores for stationary beekeeping reflect the carrying capacity of the area both in terms of honey production for the market and of sustaining the bee families throughout the season, while scores for migratory beekeeping reflect the carrying capacity of the area only in a short time period of certain species' mass flowering. Therefore, considering resilience and sustainability, we suggest to prepare maps based on the capacities for the stationary beekeeping.
Naturalness vs. anthropogenic disturbance: high naturalness and habitat diversity are usually considered to be positively affecting the honey provisioning capacity of all habitats. Meadows in good condition can have an outstanding floral richness that is not just offering pollen and nectar all through the growing season but holds high conservation value as well. Therefore, keeping a good ecological status of habitats is usually a shared goal of beekeepers and nature conservationists. In some areas that host nectar-producing invasive alien species (e.g. Robinia pseudo-acacia, Asclepias syriaca or Solidago canadensis) in high densities, degraded habitats may also be highly appreciated by beekeepers. This contradiction can be resolved with an integrated assessment approach, when trade-offs between EC and ES are analysed and areas with multiple ES highlighted.
Fixing the scale to actual biophysical quantities always involves a lot of uncertainty, which is especially true for honey provision, as this ES is extremely dependent on yearly variation of flowering success and weather.

Quality check/Pros & cons

The quality of the resulting maps can be checked with the experts (either the experts who made the rules, or other experts). Considering that the data on actually produced honey is available, experts are in a position to give very precise estimates.

Examples

The example presents results of the mapping of potential honey provision in the protected area of Bijambare, managed by the Cantonal Public Institution for the Protected Natural Areas Sarajevo, Bosnia and Herzegovina. The model behind the map follows the above described method. ET scores and rules were defined in collaboration with the experts and stakeholders from the area.
Table 8 shows the relevant ecosystem types and the scores assigned to them. Table 9 shows the additional variables and the rules along which they were incorporated in the model. Figure 19 shows the result map.

Honey provision in Bijambare	
Ecosystem type	**score**
E2.2 Low and medium altitude hay meadows	5
E4.31 Alpic [Nardus stricta] swards and related communities	2
F4.2 Dry heaths	4
G3.1 [Abies] and [Picea] woodland	5
G5.64 Raised bog pre-woods	1
D2.3 Transition mires and quaking bogs	1
G1.5 Broadleaved swamp woodland on acid peat	1
G1.6 [Fagus] woodland	5
G1.1 Riparian and gallery woodland, with dominant [Alnus], [Betula], [Populus] or [Salix]	4
F3.1 Temperate thickets and scrub	3

Table 8: ecosystem types and scores for honey provision in Bijambare.

Honey provision in Bijambare	
Variable	**Rule**
Elevation	elevation<900 → score+1
	elevation 950-1100 → score+2
	elevation>1100 → no change
Dominant vegetation type	the ET is forest → score+2
	the ET is meadow → score+1
	the ET is other habitat → no change
Anthropogenic influence	low → score+2
	middle → score+1
	high → no change
Exposition	North → score+2
	East and West → score+1
	South → no change

Table 9: additional variables and rules for honey provision in Bijambare.

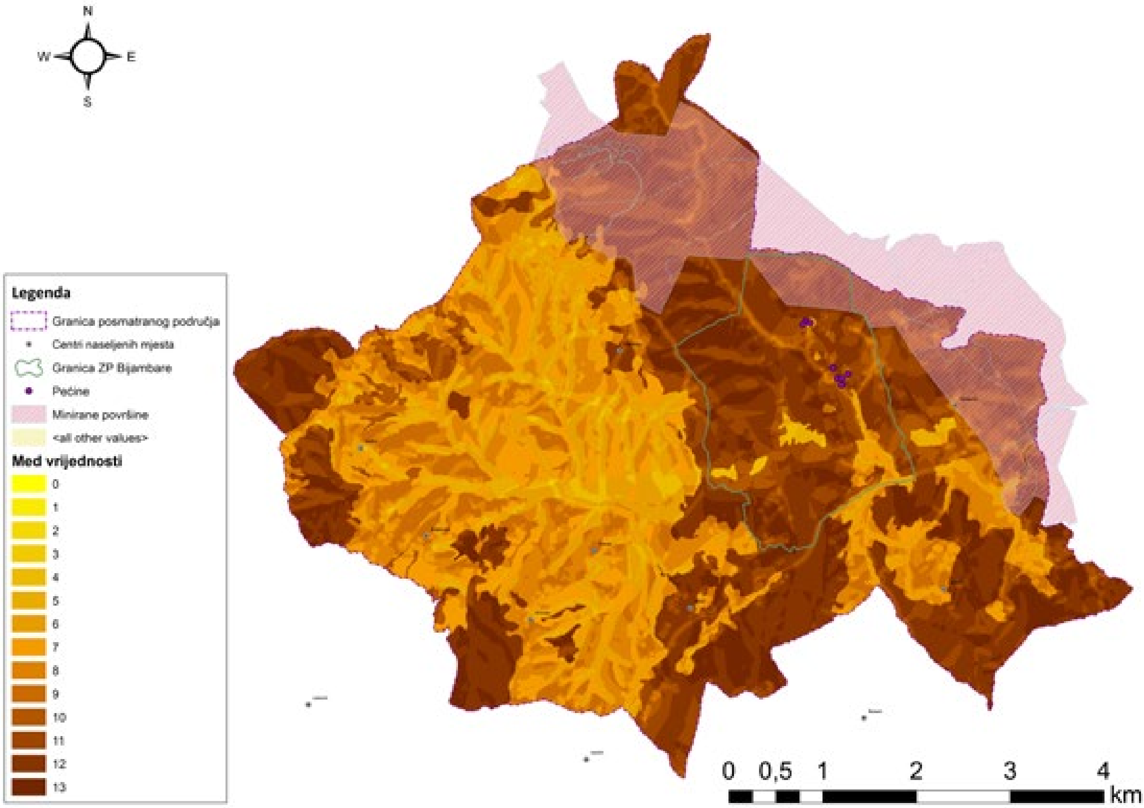


Figure 19: Honey provisioning capacity in Bijambare (by Edmir Prasovic)

Interestingly, the general importance of forests and meadows was reflected in a separate rule (dominant vegetation type), although for integrating this rule into the model, the same ET map was used as the one used for the original ET scoring. Alternatively, this can be built into the base scores on a higher level of ET classification (Eunis level 1).

Blur red represents a minefield left from the Yugoslav Wars, so that part of the area was not taken into account.

Provision of nectar and pollen for honeybees (honey)
Method 2. Map based on the occurrence of nectar producing plants

An alternative approach for mapping honey provision is based on the literature data: the occurrence of nectar producing plants. This requires good data cover of forests, arable lands and grasslands, as well as data on the species' estimated potential honey productivity. The method does not require stakeholder workshop, although validation of the results by beekeepers is necessary.

Data needs

Consult with experts concerning the exact data needs:

- map of forest tree cover shares (in pilots where forested bee pastures are relevant)
- map of crop shares in arable land (e.g. for EU member states, homogeneous soil mapping units data derived from the CAPRI database - ftp://mars.jrc.ec.europa.eu/Afoludata/Public/DS35/ (in sites dominated by agricultural use)
- occurrence of nectar producing grassland herbs (e.g. based on phytocoenological records or biotic database)
- estimated honey producing capacities of species (available in several countries in the apiculture literature).

Workflow

1. Data pre-processing:

  1.1. (In areas where forested bee pastures are relevant) Identify forest tree species particularly relevant for honey (such as spruce, fir or black locust) and derive their mixture ratios from forestry database.

  1.2. (In areas where honey from agricultural crop is relevant) Create a preliminary map of crop shares in arable land (e.g. the EU's CAPRI database includes modelled crop shares of homogeneous soil mapping units for all arable land in the EU).

  1.3. (in areas where grassland bee pastures are relevant) Identify grassland types / herb species particularly relevant for honey and map their occurrences/percentage cover per grassland based on species monitoring/biotic database/phytocoenological data.

2. Add up the species level percentages to get the total cover of the nectar producing plants in each habitat unit.

3. Optionally: assign estimated honey producing capacities to the species (based on literature data) multiplied with their cover share, and add up the species level estimated capacities to get the total honey producing capacities for each habitat unit.

4. Create a draft map based on the established model.

5. Validate results with beekeeper experts.

6. If necessary, revise literature-based potentials with yield data of local beekeepers.

Challenges

This method has been recently developed within the ECO KARST project and therefore has not yet been tested elsewhere. Several pitfalls might become apparent during the testing and validation in the coming years.
Fixing the scale to actual biophysical quantities always involves a lot of uncertainty, which is especially true for honey provision, as this ES is extremely dependent on yearly variation of flowering success and weather.

Quality check/Pros & cons

The quality of the resulting maps can be checked with the experts (either the same ones who made the rules, or others). . Considering that the data on actually produced honey is available, experts are in a position to give very precise estimates

Examples

The example presents results of the mapping of potential honey provision in the Tara National Park, Serbia. The model behind the map follows the above described method. For forests, the percentage shares of fir and spruce have been derived from the forestry database and added for each forest stands. For grasslands, the list of relevant species was extracted from the book of Umeljic (1999) and their percentage cover data have been derived from phytocoenological records of the most widespread plant communities. Since the phytocoenological sampling did not cover all the grasslands in the area, these data were extrapolated to other occurrences of the same communities within the area. Table 10 shows an example of 3 grassland communities with their nectar producing species and cover %. Figure 20 shows the result map with added percentages of nectar producing species.

Honey provision in Tara		
Grassland type	**Nectar producing species**	**% cover**
RANUNCULO NARDETUM STRICTAE	*Ranunculus montanus*	10
	Potentila erecta	10
DANTHONIETUM CALYCIANAE	*Rhyntaus rumelicus*	10
	Achilea milleofolium	10
	Filipendula hexapetala	10
	Polygala comosa	5
	Leucanthenum vulgare	5
	Trifolium montanum	5
	Trifolium pannonicum	5
	Trifolium repens	5
CARICETO BROMETUM ERECTI	*Trifolium montanum*	10
	Leucanthenum vulgare	10
	Polygala comosa	10
	Galium verum	10
	Centaurea scabiosa	5
	Lotus corniculatus	5
	Trifolium pretense	5
	Trifolium campestre	1
	Thymus pulegiodes	1
	Filependula hexapetala	1

Table 10: Occurrence and % cover of nectar producing plants of grasslands, on the example of three grassland types in Tara. Cover data are based on phytocoenological records of Tara NP.

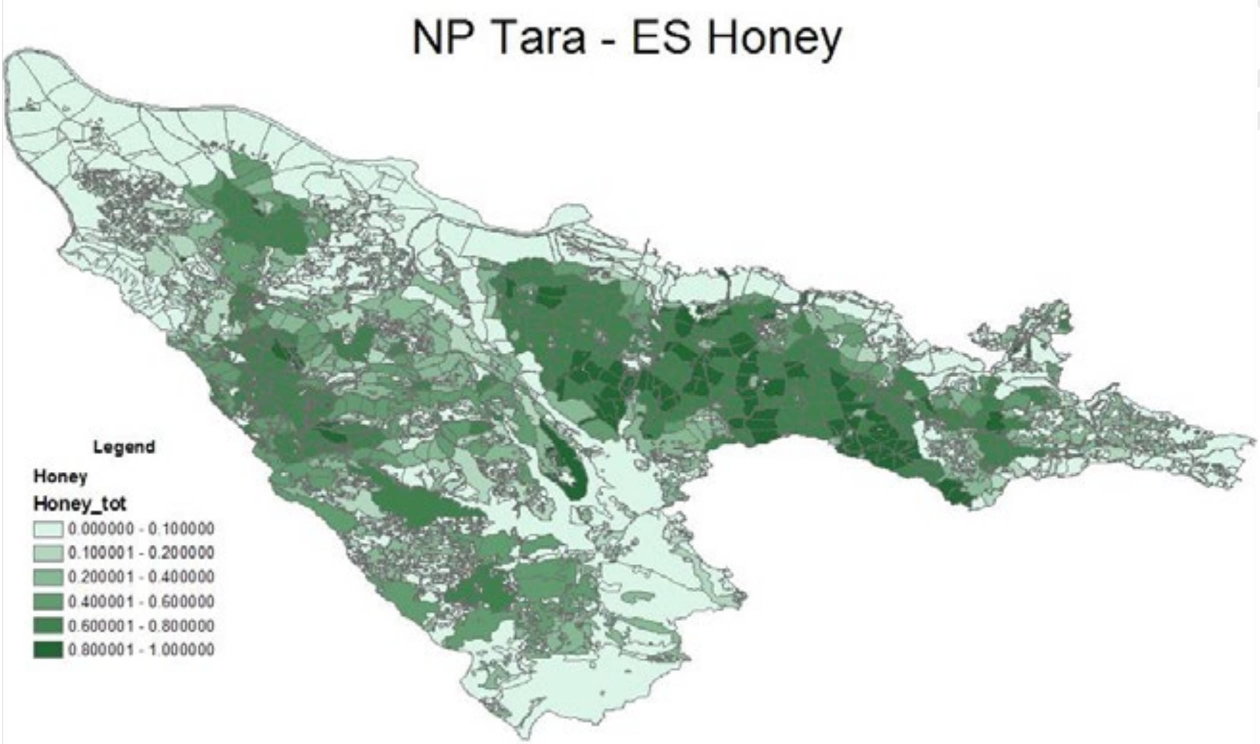


Figure 20: Honey provisioning capacity in Tara National Park according to the percentage cover of the nectar producing species in each habitat types (grasslands) and forest stands (forests) (by Marijana Josipović and Aleksandar Djurić)

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Economic Assessment of ES

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Introduction

Purpose

The economic valuation of ecosystem services (ES) is a tool to help decision makers to make more informed plans about landscape and ecosystem services management. All ES contribute to the economy in some way, but the monetary value of these contributions is often not explicitly represented on the market. One can argue that the lack of sustainable landscape management is due to this lack of information. If only decision makers knew how much value ES hold, they would consider them as an asset to be protected for future generations.

This document describes simple methods to estimate the economic value of some ES. The methods are simple and can be applied by anyone with access to the necessary data. They only provide estimations of ES monetary value and results should be interpreted in context with due consideration of the underlying assumptions.

Place in the assessment process

This is the last of the five guidance documents leading users through the process of mapping and assessment of ES. The economic assessment is a closing step after biophysical estimation of the capacity of ES. It makes results somewhat comparable, thus helping decision makers to see some trade-offs. It is important however to consider that other, non-monetary trade-offs also exist.

Skills required to complete

Economic assessment does not require numerous special skills. Good command of a spreadsheet editor like Microsoft Excel is helpful. Usually, some creativity is needed when considering possible data sources. In terms of technical knowledge, high school level mathematics is sufficient for our methodologies.

To support the calculation process, we provide a template spreadsheet in Microsoft Excel format that contains short descriptions and formulas necessary to calculate the economic value of each ES. This template can be accessed at the Eco Karst project site[1].

1 See ES_valuation_template.zip at http://www.interreg-danube.eu/approved-projects/eco-karst/outputs

Scientific background

Economic Assessment of Ecosystem Services is a popular, albeit controversial scientific field. It is essential to emphasize that monetary value never represents the full value of a commodity. It is mainly derived from its supply and demand (water is more valuable than diamonds, yet the latter are much more expensive, given that there is more water than diamonds on the planet). It is important to distinguish price (monetary value), value and importance, as the three different attributes of anything. Prices also represent the social status of the local community – a richer country means higher prices, even if the thing valued is virtually the same (Heal 2000). There are many different methodologies for the monetary assessment of ES. Many are indirect and based on surveys and other techniques to capture the value by assessing the willingness to pay for ES, as reported or revealed by users of the ES. Usually, these methods rely on complex calculations and require expertise in data collection (Kerekes, Marjainé Szerényi, and Kocsis 2018). Others are relying directly on market prices (Hein et al. 2006; Martín-López et al. 2011; Forest Europe 2018). While these methods are limited because some ES cannot be estimated as they are not marketed, in other cases they provide less controversial results since they rely on real prices instead of ''stated preferences'' or other proxies that may lead to methodological problems. Our methodology is built on the actual costs and benefits associated with the provision of ES. Thus, it measures the actual economic benefit generated for the consumer and the producer (Krieger 2001; Forest Europe 2018). Our methods lead to interesting, helpful, but somewhat limited results both in accuracy (as very simple estimation methods are often applied) and in principle (as non-market values and other invaluable attributes are openly omitted from our approach). We believe that economic assessments have to be interpreted with their limitations thoroughly considered (Spangenberg and Settele 2010) and together with other indicators and attributes of the landscape, preferably in a participatory framework (Martinez-Alier, Munda, and O'Neill 1998), where monetary values are not decisive, but rather informative, contributions to a sustainable landscape management.

General concepts and assumptions

What is the value of ES?

In this manual, we define the monetary value of ES as the net profit generated on the market, in other words, all income generated on the market – all the costs associated with selling them as products.
This definition captures the value that is represented by ES based products on the market and deducts most human labour associated with those products. There are two types of labour in this process: collecting, managing resources produced by ES and creating processed produce out of these materials. Our methods will consider only the value of the first, the raw material. Costs of labour and equipment will be subtracted, thus only the ecological output will be calculated.

Sustainability

Some ES have a high value on the market, some others have low value. Low prices do not indicate the abundance of a product and high prices do not indicate that resources are scarce. This mismatch between prices and local ecological conditions is one of the driving forces of often unsustainable landscape management practices. Prices do not reflect ecological boundaries which have to be assessed with other methods.

Selected services

In this document, we primarily consider provisioning services since they are most often sold on the market. Thus, we will provide assessment templates for **honey, medicinal herbs, timber, firewood, grazed animal meat, milk, fodder, wild game, mushroom, and wild fruit.** Additionally, we provide a method for the touristic attractiveness of nature as the most important cultural service in terms of income in protected areas.

Data collection and data sources

Data sources

Ideally, all individual producers can provide data on their businesses. This would be the most accurate option possible. However, collecting information on such scale is usually not feasible. The second-best option is to find an organization working closely with the producers that collects data locally. Typically, farmers' associations or municipalities may have such data. Local data managers are usually able to provide data for the specific area in question. If not, one of the following methods has to be applied.

Data is for a larger area than necessary

If this is not an option, national statistical service is an alternative, but these sources usually do not cover the exact area of concern. In this case, numbers have to be adjusted either by area or by the area of the relevant habitat patches if the necessary land cover data is available:

P: production in the project area
PHA: producing habitat area within your project area
DHA: data habitat area – all relevant habitats within the area where data has been collected
PD: production data – data obtained from the statistical office (e.g.: produced amount, price, etc.)

P = PHA/DHA × PD

Data is for the smaller area than necessary

If the national statistical office does not provide or only provides such data for an area much larger than what is involved in the assessment process, partial local data can be extrapolated. In this case, a smaller number of farmers provide their data, and the final results are extrapolated based on the proportion of relevant habitat patches used by them as compared to the whole area:

P: production in the project area
PHA: producing habitat area within your project area
FHA: farmers' habitat area – the sum of the area the data providers use within the project area
PF: farmers' production – the sum of production numbers from individual farmers (e.g.: produced amount, price, etc.)

$$P = PHA/FHA \times PF$$

For the latter methodology, in theory, even a single farmer's data could be sufficient, but accuracy is much bigger with as many as possible participating. The extrapolation is possible because prices and production levels have only a limited variance within one locality in most cases.

How to calculate prices with taxes?

In the calculations of ES values, we include taxes. All values should be gross, before taxes.

Purchasing Power Parities (PPP)

If an assessment is provided for national or regional use, the national currency is sufficient for all calculations. If international comparisons are planned, all prices should be calculated to a comparable form: USD at PPP rates. OECD[2] and other international institutions provide current PPP exchange rates.

Producer and consumer price

In many cases, raw produce is processed, e.g. jams made of forest fruits. In these cases, fruit is usually sold in larger quantities for lower prices to the processing company or to retailers. The lower price is the producer price. Consumers buy the raw produce directly (as fruit) without further processing, usually at a higher price. That is the consumer price. In the calculations, we distinguish between these prices (see detailed methodologies).

Collection and production

Some products, such as medicinal herbs, that can be collected from wild habitats can also be produced in agricultural landscapes or gardens. In this assessment, we only consider products from the wild habitats. Grown plants and reared wild animals are completely excluded.

Family consumption, non-marketed production

The family often does not sell a portion of the collected produce. Rather they consume it, or give it away as a present. Unless it is a significant amount (more than 10% of the production), we exclude these from our assessment.

Raw and processed produce

For every ES, we use its rawest form, before any kind of processing. This means that forest products are considered in their freshly collected form, domestic animals as living, wild game as killed but whole.

2 https://data.oecd.org/conversion/exchange-rates.htm#indicator-chart

Calculation methods

The calculation methods described below are easily reproduced in any spreadsheet editor (like Microsoft Excel). It is a good practice to collect all data for multiple years and calculate averages if possible. Ecosystem Services are highly dependent on weather and other variable processes, thus a multiple-year average is more realistic than a single year that may or may not be close to the average.

Honey

The economic value of honey as an ES is all revenue generated by honey sales within the pilot area minus all the costs that are associated with its production in a year. Only raw honey is included. If there are products containing honey as an ingredient, producer prices need to be calculated for them and should be considered as products sold in the producer market. Different honey varieties should be calculated separately.

Necessary data

P: all honey produced in a year – by type [kg/y]
Con: all honey sold to consumers yearly – by type [kg/y]
Pro: all honey sold to producers or retailers yearly – by type [kg/y]
CP: consumer price – by type [currency/kg]
PP: producer price – by type [currency/kg]
UC: production costs/unit produced – by type [currency/kg]
ESV: ES value [will be calculated below]

Calculation method

ESV = $\sum$honey types[$Con_{type1} \times CP_{type1} + Pro_{type1} \times PP_{type1} - P_{type1} \times UC_{type1}$]

The formula in brackets should be calculated for each type of honey separately and added up to get the final ESV value.

Medicinal herbs

The economic value of medicinal herbs as an ES is all revenue generated by medicinal herb sales within the pilot area minus all the costs that are associated with its production in a year. Only fresh and naturally dried (on the air, sun without using machines) medicinal herbs that were not mixed and packaged separately are included in the calculation. If there are products containing medicinal herbs as an ingredient, producer prices need to be calculated for them and they should be considered products sold in the producer market. Different varieties should be calculated separately for each plant species.

Necessary data

P: all herbs collected in a year – by type [kg/y]
Con: all herbs sold to consumers yearly – by type [kg/y]
Pro: all herbs sold to producers or retailers yearly – by type [kg/y]
CP: consumer price – by type [currency/kg]
PP: producer price – by type [currency/kg]
UC: collection costs/unit collected – by type [currency/kg]
ESV: ES value [will be calculated below]

Calculation method

ESV = $\sum$herb species[$Con_{type1} \times CP_{type1} + Pro_{type1} \times PP_{type1} - P_{type1} \times UC_{type1}$]

The formula in brackets should be calculated for each type of herb separately and added up to get the final ESV value.

Timber

Timber is wood harvested for use in building and carpentry. We make a distinction between timber and firewood because their use, quality and prices are different. The economic value of timber as an ES is all revenue generated by timber sales within the pilot area minus all the costs that are associated with its production in a year. Only timber without further processing is included. If there are products made of timber (e.g. furniture, paper), producer prices need to be calculated for them and they should be considered products sold in the producer market. We calculate timber prices for forest cubic meters separately for each species.

Necessary data

P: all timber produced in a year – by type [m3/y]
Con: all timber sold to consumers – by type [m3/y]
Pro: all timber sold to producers or retailers – by type [m3/y]
CP: consumer price – by type [currency/m3]
PP: producer price – by type [currency/m3]
UC: production costs/unit produced – by type [currency/m3]
ESV: ES value [will be calculated below]

Calculation method

ESV = $\sum$timber species[$Con_{type1} \times CP_{type1} + Pro_{type1} \times PP_{type1} - P_{type1} \times UC_{type1}$]

The formula in brackets should be calculated for each type of timber separately and added up to get the final ESV value.

Firewood

Firewood is wood burnt as fuel. The economic value of firewood as an ES is all revenue generated by firewood sales within the pilot area minus all the costs that are associated with its production in a year. If there are no significant price differences, different species do not have to be considered separately.

Necessary data

P: all firewood produced in a year [m3/y]
Con: all firewood sold to consumers in a year [m3/y]
Pro: all firewood sold to producers or retailers in a year [m3/y]
CP: consumer price [currency/m3]
PP: producer price [currency/m3]
UC: production costs/unit produced [currency/m3]
ESV: ES value [will be calculated below]

Calculation method

ESV = Con × CP + Pro × PP – P × UC

Grazed animal meat

The economic value of meat from grazed animals as an ES is all revenue generated by meat sales based on the quantities and prices of live animals within the pilot area minus all the costs that are associated with its production in a year. We only consider all animals that are grazed at least 100 days a year. We use the price of the living animal to avoid problems caused by price differences among different parts of the animal. We calculate the economic value for each species separately.

Necessary data

P: all animals in the area in a year – by species [unit/y]
Con: all animals sold to consumers yearly – by species [unit/y]
Pro: all animals sold to producers or retailers yearly – by species [unit/y]
CP: consumer price – by species [currency/kg]
PP: producer price – by type [currency/kg]
UC: production costs/animal – by type [currency/unit]
ESV: ES value [will be calculated below]

The unit used for the counting of animals may depend on the dataset available. Kilograms will be more accurate, but animals may only be measured in a documented manner when they are sold.

Calculation method

ESV = $\sum$animal species[$Con_{type1} \times CP_{type1} + Pro_{type1} \times PP_{type1} - P_{type1} \times UC_{type1}$]
The formula in brackets should be calculated for each species of animal separately and added up to get the final ESV value.

Grazed animal milk

The economic value of milk as an ES is all revenue generated by milk sales within the pilot area minus all the costs that are associated with its production in a year. Only raw milk is included. If there are products made of or containing locally produced milk as a raw material or an ingredient respectively (e.g.: cheese, cream), producer prices need to be calculated for them and they should be considered products sold in the producer market. Milk of different animals should be calculated separately.

Necessary data

P: all milk produced in the area per year – by species [l/y]
Con: all milk sold to consumers yearly – by species [l/y]
Pro: all milk sold to producers or retailers yearly – by species [l/y]
CP: consumer price – by species [currency/kg]
PP: producer price – by type [currency/kg]
UC: production costs/unit – by type [currency/l]
ESV: ES value [will be calculated below]

Calculation method

ESV = $\sum$milk by species[$Con_{type1} \times CP_{type1} + Pro_{type1} \times PP_{type1} - P_{type1} \times UC_{type1}$]

The formula in brackets should be calculated for each species of animal separately and added up to get the final ESV value.

Fodder

The economic value of fodder as an ES is all revenue

generated by fodder sales within the pilot area minus all the costs that are associated with its production in a year. Fodder is usually measured in bales, but its size varies across regions. Therefore, we calculate fodder in kilograms and ask for converting the local bales into kilograms. We assume that fodder is sold only in the producer market. If in your region there is a significant market for fodder on the consumer market, extend the methodology below based on the descriptions of other ESs. Different plants are not considered separately in this method.

Necessary data

P: all fodder produced in a year [kg/y]
Pro: all fodder sold to producers or retailers [kg/y]
PP: producer price [currency/kg]
UC: production costs/unit [currency/kg]
ESV: ES value [will be calculated below]

Calculation method

ESV = Pro × PP – P × UC

Wild animal meat

The economic value of meat from wild animals as an ES is all revenue generated by meat sales based on the quantities and prices of unprocessed animals within the project area minus all the costs that are associated with its production (e.g. feeding) in a year. Prices should be calculated by species separately.

Necessary data

P: all animals killed in the area in a year – by species [unit/y]
Con: all animals sold to consumers in a year – by species [unit/y]
Pro: all animals sold to producers or retailers in a year – by species [unit/y]
CP: consumer price – by species [currency/kg]
PP: producer price – by species [currency/kg]
UC: production costs (e.g. winter-feeding)/unit – by species [currency/unit]
ESV: ES value [will be calculated below]

The unit used for the counting of animals may depend on the dataset available. Kilograms will be the most accurate if that data is available.

Calculation method

$ESV = \sum_{\text{animal species}}[Con_{type1} \times CP_{type1} + Pro_{type1} \times PP_{type1} - P_{type1} \times UC_{type1}]$

The formula in brackets should be calculated for each species of animal separately and added up to get the final ESV value.

Mushrooms

The economic value of wild mushrooms as an ES is all revenue generated by wild mushroom sales within the pilot area minus all the costs that are associated with their collection in a year. Only fresh and naturally dried (on the air, sun, without machines) wild mushrooms are included in the calculation. Mushrooms grown in any controlled environment are excluded. We separate calculations by species.

Necessary data

P: all mushroom collected in a year – by species [kg/y]
Con: all mushroom sold to consumers in a year – by species [kg/y]
Pro: all mushroom sold to producers or retailers in a year – by species [kg/y]
CP: consumer price – by type [currency/kg]
PP: producer price – by type [currency/kg]
UC: collection costs/unit – by type [currency/kg]
ESV: ES value [will be calculated below]

Calculation method

ESV = $\sum$mushroom species$[Con_{type1} \times CP_{type1} + Pro_{type1} \times PP_{type1} - P_{type1} \times UC_{type1}]$

The formula in brackets should be calculated for each type of mushroom separately and added up to get the final ESV value.

Wild fruits

The economic value of wild fruit as an ES is all revenue generated by wild fruit sales within the pilot area minus all the costs that are associated with its production in a year. Only fresh and raw wild fruit is included in the calculation. If there are products available containing wild fruit as an ingredient, producer prices need to be calculated for them and they should be considered products sold in the producer market. We calculate prices separately species by species. Fruits grown in gardens or orchards should be excluded, only collected wild products are included.

Necessary data

P: all fruits collected in a year – by species [kg/y]
Con: all fruits sold to consumers in a year – by species [kg/y]
Pro: all fruits sold to producers or retailers in a year – by species [kg/y]
CP: consumer price – by type [currency/kg]
PP: producer price – by type [currency/kg]
UC: collection costs per unit – by type [currency/kg]
ESV: ES value [will be calculated below]

Calculation method

ESV = $\sum$forestfruit species$[Con_{type1} \times CP_{type1} + Pro_{type1} \times PP_{type1} - P_{type1} \times UC_{type1}]$

The formula in brackets should be calculated for each type of forest fruit separately and added up to get the final ESV value.

Touristic attractiveness of

nature

The economic value of touristic attractiveness of nature as an ES is all revenue generated by "nature tourism" within the assessment area minus all the costs that are associated with it in a year. The extent of nature tourism will be estimated by calculating the rate of time spent on nature tourism within all touristic activities in the area. The proportion of nature tourism compared to all touristic activities has to be calculated.

With the following method, we assume that tourism is only generated by a set of attractions of diverse nature (N or C) and popularity (POP). We also assume that individual tourists have multiple reasons to come to a place, thus it is impossible to distinguish between ES tourists and cultural tourists. Tourists do not just visit attractions, but also eat at restaurants, stay at hotels, etc., but these expenses would not happen without the attractions.

Using these assumptions we can calculate the value of touristic attractiveness of nature by calculating the proportion of the total attractiveness of the area provided by nature and multiplying it by the total income generated by tourism – thus getting the total income generated by nature on average.

The obvious challenge is to determine the list of attractions (A). This is a qualitative process that cannot be formalized and should be done in a participatory way using a large group of local people if possible. If this list is biased, the calculation will also be biased, thus it is recommended that selection criteria are determined before compiling the list by the participants of the selection process. The group should not include general attractions like the "beauty of the mountains". Special spots, like lookout points, can be included since visitor numbers can be estimated roughly at these places.

Necessary data

V: number of visitors in a year in the area [No. of people × No. of nights/year]

I: income of tourism within the area in a year (all type of touristic activities together including hotels, restaurants, entrance fees, rental fees, etc.) [currency/year]

UC: costs of tourism within the area in a year – by income type (calculated separately for hotels, restaurants, etc. depending on data availability) [currency/ person/occasion | night | entrance]

A1-n: attractions in the region both "natural" and "cultural", they should be sorted into two categories: "N" – natural and "C" – cultural. ["N", "C"]

POP1-n: relative popularity of the individual attractions (A1-An) most popular = 10, least popular = 1, all attraction should be scored by a small group of local experts who are familiar with visitor numbers. If possible, scores should be determined by the proportion of visitor numbers (V) for each separate attraction ["1" – "10"]

ESV: ES value [will be calculated below]

ESP: ES popularity index [will be calculated below]

Calculation method

ESP = (∑POP where Ai = "N")/(∑POP for all A)

ESP is the sum of popularity scores of natural attractions divided by the sum of popularity scores of all attractions.

ESV = ESP × I – V × UC

Interpretation of results

Landscape planning or protected area management involves a multitude of options, stakeholders and different interests. The monetary valuation of ES can contribute to a fruitful discussion about the future of a protected area by highlighting how many people depend on it, how many businesses rely on it and how unnecessary investment is given the free services nature provides. The methodologies in this manual are conservative estimates as they only estimate private benefits obtained from ES and we have not provided methods for other value-dimensions such as public values, which is probably the most important aspect of regulating services, that are not discussed in this document. When interpreting the results of these estimates, all stakeholders have to bear in mind, that the results are usually lower than the actual monetary contribution of ES, thus harming the capacity of the habitats to provide these services could result in high losses even in cases when gains were estimated lower. It is also possible that prices show a high level of income, but due to the unsustainable management of the landscape, future losses or landscape degradation is to be expected. A multi-criteria analysis, described by Martinez-Alier and his colleagues is a practical tool to handle this complex situation. In this method, besides economic valuations, other social and ecological aspects can also be taken into account (Martinez-Alier, Munda, and O'Neill 1998).

Another aspect that has to be taken into account is the trajectory of change over time. As these calculations are based on the actual use of the ES, both growth and decline of the numbers is a matter of concern. If ES use declines, it can be a consequence of market processes, declining habitat condition or sociological processes, such as migration of local inhabitants to other places. Similarly, an increase can be an indicator of a better habitat condition, overharvesting or some socio-economic change.

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